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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

TRANSACTIONS FOR 1880.

PLACE OF MEETING AND OFFICES:

THE SOCIETY'S HALL, No. 6, WESTMINSTER CHAMBERS,
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1881.

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PREMIUMS FOR 1880.

At a meeting of the Society, held on February 7th, 1881, a Premium of Books was awarded to:

GEORGE M. WARD, for his paper on "The Utilisation of Coal Slack in the Manufacture of Coke for Smelting."

And to:

W. WORBY BEAUMONT, for his paper on "Modern Steel as a Structural Material."

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

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TRANSACTIONS, &c.

February 2nd, 1880.

INAUGURAL ADDRESS.

By JOSEPH BERNAYS, President.

On assuming for the first time the Chair of our Society as President, my first and most agreeable duty is to render you, gentlemen, my cordial thanks for the honour you have done me by your selection. To occupy this Chair is, and always will be, a coveted mark of distinction, and the ambition to reach this position is both legitimate and honourable. As regards myself, I own that I was doubtful for some time whether I should be doing right in accepting it, one of the reasons for which was that, not being an Englishman, occasions might arise when I might not be able so efficiently to discharge my official duties, as one would do who was born in these islands. I have, however, resided on this soil for such a length of time, and feel myself so much amongst friends here that, taken together with the very amiable expressions of the whole Council and your own kindly feelings towards myself, I am entirely reassured on this point. Another reason for my hesitation, and one of vastly greater importance to the interests of our Society, is the fact that my whole professional practice has hitherto been of a private character only, and I have not done anything to bring my name prominently before the professional world so that my accession to the Chair would of itself prove of beneficial influence for our Society. That such public renown and distinction are qualities in a President very acceptable and desirable in the interest of our Society, I need not specially dwell upon, seeing that for the last two years we have had a gentleman in the Chair, who so well exemplified the very points I have been mentioning, and who has occupied that position with such great efficiency and dignity. Nor need I confine myself to my immediate predecessor in the Chair for the recognition of the qualities which go to make a successful President, inasmuch as

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our Society has hitherto been eminently successful in the choice of its Presidents, each and all of whom have discharged their duties in a manner highly creditable to themselves and useful to us. If I may hardly hope to fulfil the duties of my office with the erudition and professional eminence of some, the originality of others, the efficiency and geniality or the capacity and energy of yet another, I can at least emulate them in the hearty good-will I bring to the work, and in the attention I may give to the duties embraced in the position. And I keep well within the mark if I say that my best efforts shall not fail to the desired end, for it is my ambition, if I am spared to the conclusion of my official year, to leave the general position of the Society in as good a state to my successor in the Chair as it is handed over to me, even if it be denied me to improve upon it.

But, gentlemen, you must permit me to remind you here, at the very outset, that the welfare and success of our Society does not in reality depend upon the qualities of the President. Neither does it depend upon those of the Council or of the officers of the Society. Each of these component parts may have some slight influence, some passing effect upon its advancement, but its welfare and its position amongst the professional world depend upon your own exertions and your own efforts to keep up its prestige. A professional and scientific body like that to which we have the honour of belonging, can only be kept going, can only fulfil its destiny, which is the general advancement of the Members in their professional course, by an active interchange of facts and opinions of a professional nature. If we relax our efforts in this respect, if we slacken our exertions in bringing forward good and thoughtful papers on subjects with which we are acquainted, no efforts on the part of your Council or of your President will keep our bonds together. This subject has been so well and ably treated from the Chair on several previous occasions that I will not occupy your time by dwelling longer upon it. But it is a matter of too great importance for us all to be passed over entirely in silence, as the very life of our Society depends upon it. I am perfectly aware that the preparation of a satisfactory paper, with its accompanying drawings, is by no means an easy matter. It requires a large amount of time, which a professional man cannot readily spare, even with the best intentions. But I may suggest to those who have difficulty in selecting a time wherein to write their paper that, after choosing a subject on which to dilate, they will find it a very useful thing to write out rough notes in irregular order at odd times and occasions when they may happen to find an hour in hand for which they have not previously arranged other

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work. A note written upon the subject is so much work finished and done, and it can easily afterwards be fitted in its proper place in the paper. It is wonderful how soon and how easily such notes accumulate, and how enticing they are as inducements to further labour. What I may call the skeleton of a paper thus readily attains its full growth and dimensions, and, with slight additional loss of time, is filled in, and rounded off to assume its definite shape.

I must apologise to the meeting for taking up its time with making such a simple suggestion, but to those of our younger Members who are not accustomed to write much the hint may prove of advantage, and you will therefore excuse the slight digression.

It would also be desirable to have a somewhat fuller attendance at our ordinary meetings. Many gentlemen will attend only when some paper referring more particularly to their own professional branch is being brought before us, and I maintain that this is hardly the correct way of looking at the meetings of a scientific Society. The papers with which we are favoured bring before us, in an easy and comprehensive style, the results of the practice and study of individual Members in their respective branches that may have taken them years, or even a whole lifetime, to collect. Now Engineers, with few exceptions, cannot generally choose exclusively, according to their own likings or predilections, the branches of the profession in which alone they would like to practise. They must, on the contrary, be prepared to take up a variety of subjects, such as at various times and under various conditions are presented to them. Under these circumstances, to hear a well-digested paper read gives an insight in the shortest and most agreeable way even in a new subject, which to master *de novo* would take very considerable time, and might not always lead to satisfactory results. As regards the enrolment of new Members, I wish to call your attention to the fact that our rooms constitute an excellent meeting-ground for such Members of other similar Societies and Institutions as find their papers and essays crowded out through the number of communications on the books of their respective bodies. We form, as it were, a connecting link between other professional bodies, inasmuch as we are open to the discussion of all professional and scientific subjects bearing on the whole range of engineering practice without limitation. We are antagonistic to no other kindred body. As a matter of fact, many of our Members are also Members of other institutions, and we have both room in our meeting-hall, as well as evenings at our disposal, to easily accommodate from

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150 to 200 more Members. We offer, in comparison with other Societies, a few advantages—such as perfectly free and unrestricted discussion within reasonable limits; the almost concurrent publication of all valuable papers in several eminent engineering journals; regular visits of our Society to interesting works in and about London, combined with some pleasant social gatherings, &c., in addition to the ordinary accommodations of library, reading-room, the issuing of the 'Transactions' and other matters. We have always considered ourselves more or less as a preparatory body for facilitating—though quite independent of them—the entry into the older institutions, most of which have a "specialist" character; and I therefore address myself with full confidence, particularly to the younger members of the profession and of those institutions, in asking them to join us, to fill up our ranks, and to support us in our earnest desire to draw still closer the bonds of friendship and mutual esteem which unite us to all our professional brethren.

In selecting a subject on which more particularly to address you this evening, I took the opportunity to refresh my memory, through the means of our 'Transactions,' as to what had been done by my predecessors on similar occasions. I found that some have favoured us with valuable contributions from the practice of those branches of the profession with which they have been more directly connected. Thus we have had some excellent discourses on Sanitary Engineering and Water Supply, on Railway matters, Gasworks, the Electric Light, and other interesting subjects. I should have been glad to follow in the footsteps of those gentlemen. But though my practice has been varied indeed since the time when, in my nineteenth year of age, I was first entrusted with laying out on my own responsibility a small engineering works and steam saw-mill combined, I have not been engaged, as stated in an earlier part of this Address, on any matter of great public importance. I should, therefore, be afraid of wearying you were I to give a record of the variety of smaller matters I have been engaged on, and have consequently abandoned that idea.

Others have given us a clear digest of the progress made in works connected with our profession generally, during the years immediately preceding their accession to the Chair, and have brought before our minds' eye many great examples of engineering from all parts of the world, tending to enhance our love for, and pride in, the profession to which we belong. It will necessarily be my privilege this evening to refer to a few such works, either in execution or in contemplation; but

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the task of bringing such matters exhaustively before you is now so well and systematically carried out at the change of each year by our various scientific and professional contemporaries, that the mere enumeration of works of engineering skill and enterprise would be a matter of supererogation, and I do not therefore think it proper to inflict upon you what would amount more or less to a repetition.

Others, again, of my predecessors have treated us to subjects of a more abstract nature—abstract only in so far that they did not immediately apply or refer to concrete matter, but of a very practical nature nevertheless. I need only mention, as an example, the very remarkable discourse on "The Engineer's Place in Nature," placed before us not many years ago on a similar occasion, an address full of thought and wisdom, and highly appreciated by us all.

For my own purpose this evening, I have selected as a subject, "The Position of our Society in its Relation to the Profession at Large," a subject which I thought would be sure to interest you all, and for the sake of which I might venture to take up a little of your time. The way in which I propose to deal with the matter will be simply to show that the papers read before us and discussed between us, as well as our vacation visits, are closely connected with many of the most important subjects of the present day. This will go far to prove that our claim as one of the means at the disposal of the young Engineer for further professional education, and at the disposal of the more advanced for active and practical interchange of opinion, is fully substantiated by the facts of the case. Each class of papers and vacation meetings will also give me the ready opportunity of referring to engineering works and other matters connected with the general subject outside of our Society, and a few of them will, in addition, enable me to make suggestions of my own—suggestions which I must submit to your indulgent criticism.

If I do not take our papers and visits in regular rotation, but in a rather disjointed fashion, I trust that you may nevertheless detect method in the apparent disorder.

To plunge at once *in medias res*, I will begin with a subject interesting to everybody, both to Engineers and to the public, inasmuch as all of us are making daily and hourly use of it, viz. Railways. We have had two interesting papers referring thereto during the year. One of them was read by Mr. Thomas Andrews, of the Wortley Ironworks, on "The Strength of Wrought-iron Axles." A paper which showed considerable application

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and research, and was considered of sufficient merit to be adjudged by the Council, the second prize of the year, as you have witnessed this evening. The second paper was by Mr. E. D. Barker, entitled "Hydraulic Continuous and Automatic Brakes," forming a continuation of a paper prepared by the same author in a previous year. Mr. Andrews, after giving an interesting account of the history of those ancient ironworks of which he is the proprietor, drew a comparison between the relative merits of steel and iron axles, inclining rather more favourably to the application of the latter material, as showing greater comparative elasticity and toughness in actual practice than those steel samples which had come under his observation. He gave us a record of an extensive number of trials carried out in the manner usually adopted, by allowing a heavy weight to fall from a measured height on an axle in the middle of its length, the ends being supported. The blows were repeated many times, the deflection recorded in each case thus forming a comparative measure of strength. His experiments led Mr. Andrews to the conclusion, that the violent tests applied under the above method, leading generally to the destruction, or at least deformation, of the axle, was hardly the best way of treating an object that had afterwards to be made use of under a railway carriage. Many must agree with him in that opinion. Nevertheless many Engineers in their specifications seem still to adhere to that condition, in some cases with the proviso that one axle only out of a certain fixed number, selected promiscuously, is to be treated in that way, and to be taken as representing the workmanship and endurance of the rest. Now to my mind the best way of testing any machinery part whatsoever, is to subject it to a class of strains similar to those which it will later have to bear in actual practice, and differing therefrom only in degree. Thus a railway axle, when under a vehicle, has four points of application of the strains: in the bearings and in the shoulders at the wheel-naves. It is subjected to bending and torsional strains and to concussions, the maximum amount of which, jointly and severally, can or may be ascertained with tolerable accuracy beforehand, and I do not think it would be difficult to devise an apparatus which should put similar strains upon the axle at such an increased ratio as might be determined in advance. Such testing would not injure the material if constitutionally sound, and could therefore be safely applied to every individual axle. If it were the intention of comparing the results of the specifications of several Engineers with each other, it might suffice to strain to destruction a few axles made according to each specification,

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and to award the palm to that which showed the best result. But such is, generally speaking, not the object of the test. We take the specification for granted, as being based on previous experience, and what we wish to detect is any slight fault, negligence, or accidental omission that may have occurred in the manipulation of any particular axle of apparently sound construction. It is that one faulty piece we wish to exclude, and with this in view it would appear natural that every separate axle should undergo the test, but to such an extent only, as to keep well within the limits of elasticity.

Referring to Mr. Barker's paper I may say, generally, that it brought before us again the question of continuous railway brakes, a very large and important subject indeed, which had on several previous occasions engaged the attention of our Society. Mr. Barker principally described the improvements made in many parts of his apparatus since its previous introduction to us. Not only was the accumulator, which is used for bringing into instantaneous action all the brake blocks under one train, much simplified and kept at an equal pressure by the direct use of steam, but the whole apparatus had now also been brought within the Board of Trade rules for continuous railway brakes. It is now capable of being put in action either by the driver or by the guard at discretion, and also becomes automatic in certain emergencies so as to guard against accidents in the most immediate and efficient manner.

Thus there are now in the market several really excellent continuous brakes, which carries us a step nearer to that desirable moment when we shall be able to say to the railway companies that it depends solely and entirely upon their own energy and goodwill to relieve us from that class of accidents against which continuous brakes have been especially designed. We cannot be said to have reached anything like perfection yet in regard to immunity from railway accidents, for taking the statistics of the year 1878, which are the latest to hand for a complete year, we find that not less than 1053 persons have been killed, and 4007 injured during that period on railways in the United Kingdom.

It has been computed that during the same period the enormous number of 700 millions of passengers have been carried on the railways, and from those figures it would be easy to calculate, in apology of railway management, how many years any single individual could travel on British lines with impunity before meeting with accident of any kind. The figure thus calculated, representing several hundred years, would show a very high degree of security, but looked at in

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this way it is entirely fallacious and misleading. Not only would it be much more fair and reasonable to count the number of trains running rather than the number of passengers carried, and compare with the number of accidents met with by those trains rather than casualties amongst the passengers; but even then, if the figures showed a high exemption, they would not give a fair estimate of the danger incurred by travellers. However proportionally far any danger might appear to be by calculation, as a matter of fact a railway accident may happen to any one of us any day without any warning, and thus the matter be brought unpleasantly near to us, figures to the contrary notwithstanding. Thus it becomes our duty as Engineers to devise means against the occurrence of such accidents, and when such means have been provided our railway companies are in duty bound to use them; for it must be borne in mind that what previously may have been termed an "accident" with some show of reason, can no longer be put under that category once adequate means of prevention being known. I do not mean by this to convey to you the idea that railway companies altogether disregard their responsibilities in the matter, for here again statistics come to my aid, and tell me that at the end of June last year (1879), out of 4764 engines in use in the United Kingdom, 907 were fitted with continuous brakes, and out of 39,827 carriages and vans 9919 had been so fitted. This is encouraging as far as it goes, but much more remains to be done.

I would, however, wish to raise the whole question as to whether, with the present necessarily complicated arrangement of railway management under a mixed passenger and goods traffic, we are ever likely to be reasonably clear of railway accidents. Taking all things into consideration, it will really appear wonderful that more accidents do not happen. It would take up too much of our time this evening were I to enter into any details on this subject, or to refer to a tithe only of the many small causes that are liable at any moment to throw the working of any of our railway lines into the greatest confusion. I need only just mention as an instance any general holiday, in connection with which a large number of passengers, or of goods and parcels, require dispatching. The result is known to you all, not only in regard to every species of discomfort and inconvenience, but also in the fact that so-called railway accidents are always expected to appear during such times of pressure, expectations in which I am sorry to say we are very rarely disappointed. Now I ask why should all this be? Why should the great highways of the country, the arteries

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and means of circulation within the national body be thus periodically choked and thrown into disorder, until purged by some "accident," bringing death and desolation home to many a hearth?

Might it not be possible so to separate the goods traffic from the passenger traffic as to be in no way a hindrance to each other? I do not mean merely to double the track, such as some of our main trunk lines, overgorged with traffic, have lately been forced to do, but to keep the passenger and the carrying traffic on our main routes in separate hands throughout—line, stations, management and all. The idea may appear Utopian, owing to the supposed great expense of such an undertaking, but on attacking the subject with a will, I am assured that this would not prove so formidable as it might appear at first sight. I am not quite alone in this view, for even within the last twelve months a scheme has been broached, and been seriously taken into consideration, proposing to start a separate railway company for the sole and single purpose of bringing coal direct from Yorkshire into London. Surely if it would pay to make a line for the accommodation of one single product only, it should pay all the better if the whole goods traffic could be carried on that same line. Nor would such railways necessarily cause a falling off in the dividends of our present lines. If the goods traffic of the latter is now in some instances the main stay of the company, it is because their passenger traffic is unnecessarily and heavily handicapped by the induced irregularity and complication of the service, necessitating a vast and costly array of arrangements and appliances, and a very army of servants, which not only add to the first cost, but more particularly to the working expenses. Such companies could hand over their goods lines and rolling stock for goods to the new carriers at a valuation, and thus relieved from an incubus which has been heavily resting on their shoulders since their first installation, they would reduce their expenses to a large extent, and greatly augment the frequency and regularity of their passenger trains.

This is not the moment to further dilate on the subject. It is sufficient for me to have called your attention to a matter of importance, and I must leave the further consideration of it to others.

From railways to tramways is a natural transition, the subject being one which, to the Engineer at the present time, is almost of equal importance, and is daily growing in value.

During the past year we have had one paper thereon, read by Mr. Wilkinson Jones, and entitled "Modern Tramway Con-

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struction," in which the author gave us a description of various systems of construction approved of and in actual use at the present time, including iron and steel rails, wood, iron, and other sleepers, in various combinations. During the discussion which followed, several more systems were mentioned, and attention was drawn to a new class of sleepers made out of blast-furnace slag, which material lent itself readily to being moulded in any convenient shape, and combining great hardness with sufficient toughness for forming a good substructure for the tram-rails to rest upon. No opinion can, however, yet be expressed on the suitability of this material until lengthened trials in actual use shall have been made, though its application is of sufficient novelty to permit of its being mentioned in this place. The general conclusion that could be drawn from Mr. Jones's paper itself, and from the animated discussion succeeding it, was, that the permanent way of tramways cannot be laid in too sound and too solid a manner, capable of withstanding not only its own legitimate traffic, but also the large amount of cross traffic, which so much conduces to the destruction of the line. It is in this respect of cross traffic that the principal difference is to be sought between tramway lines and ordinary railway lines, and as steam traction is substituted more and more for horse traction on tramways, the question of vehicular cross traffic will gradually grow to represent almost the only difference in construction that has to be taken into account in the two classes of railways. Money spent on a sound substructure for a tramway is money well laid out, and sure to pay in the end. We cannot as yet be said to have reached perfection, nor anything near it, in the way our tramways are laid and constructed; nor can I think that such a point will be reached until the local authorities shall have been brought to see that the tramway and the road through which it is to pass must be treated as one indivisible whole, and that neither can be altered or disturbed without affecting the other. Engineers will then be able to scheme out and arrange for the construction of the combined road and tramway with much greater chances of success than they have at present. If the system of steam traction on tramways, to which we, as Engineers, have every reason for wishing success, is to come into more general use in the outskirts of populated towns and as means of communication between adjacent places, much greater attention must be given to that question than obtains at present. A very large accession has been made to tramways during the past year both in England and abroad, mostly worked by horses or mules, but some also by steam power, and

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it is not too much to say that for some years to come tramways will multiply in an increasing ratio. They must therefore be considered as a valuable addition to the repertory of works going through the hands of the Engineer, and as such have his best care and attention.

The subject of ordinary road making will next claim our notice. It is one of acknowledged importance in all civilized countries, and will always remain prominent, however much other methods or means of transit may multiply. The subject has been treated before our Society very fully in previous years, but during the past year the only contribution in any way relating thereto was offered by Mr. Charles E. Hall, in his paper "On Modern Machinery for preparing Macadam for Roads." After giving a description of the various stone-breaking machines in the market, Mr. Hall described an arrangement of machinery composed of well-known and approved patterns, calculated to break and separate the various sizes of stones used in the construction of macadamized roads in the most efficient and economical manner. The author's object being to supply the necessary amount of broken material at the least cost, with little waste, and with the smallest amount of wear and tear to the machinery. He seems to have succeeded in the task he set himself, as he was enabled to show a sensible reduction from the ordinary cost of broken material as usually prepared, a statement which was corroborated by several gentlemen conversant with the subject who took part in the discussion.

The macadamized road, as left us by Telford and Macadam, still holds its own in spite of the great alteration that has taken place in the class of traffic which passes over it, thus giving additional proof, if such were needed, of the talent displayed, and foresight exercised, by our great pioneers of engineering. For I hold, and you will agree with me, that nothing more distinctly proves the power and genius of an Engineer, nor the value of a new invention or application of his, than to find that the system on which he worked or to which his invention applied, will endure unaltered, and in the face of strong competition, not for some years only, but for ages. Of such is the macadamized road, and it really still makes the best and most suitable surface for the highways and byways of the country and for roads between inhabited districts, where it is found to be the cheapest that can be laid, and the easiest to repair. But it is a different matter where the roads within populated towns and crowded thoroughfares are to be considered, such as they exist in this metropolis and in many large towns in the country. Macadamized roads were never intended for

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such situations, and in such places we must hope that their days are numbered. For constant and heavy traffic, combined with high speed, as it occurs in all important towns, a macadamized road becomes a nuisance, it requires everlasting repairs, and consequent stoppage of the traffic, it damages and wears out the better class of vehicles passing over it to an alarming extent, and is dirty, unwholesome, and unpleasant in all weathers. Luckily it has been proved by many careful experiments, carried out in various positions, that under the last-mentioned conditions the maintenance of a macadamized road is a very expensive affair indeed, and we may therefore hope that the various sanitary or other local boards may soon be compelled, by the action of the ratepayers, to abandon macadam in important central situations. There are many first-class materials at hand, and approved of, for the construction of the surface of roads and streets in towns, such as granite setts, asphalte, and wood pavements, the use of either of which instead of macadam, according to the circumstances that lead to adoption in each special case, will be hailed with satisfaction by all users of the road.

The next paper which I shall have to notice was read by Mr. Henry Robinson, M.I.C.E., entitled "Sewage Disposal." The author therein gave us the results of his extensive experience in this branch of the profession, and referred to the various systems tried and in use in recent years. He pointed out how very frequently the salutary laws laid down by the Legislature for the proper drainage of inhabited places are transgressed, with the usual consequences of disease and death following in the train of such transgression. He treated the question of water supply as one intimately connected with proper drainage, and made out a very strong case for the general introduction of the constant supply system. It is very evident that the question of the proper disposal of sewage is as much a vexed question now in many cases as it ever has been before, complicated as it is by considerations of economy, health, and the purification of our rivers. The present state of the case may shortly be put as follows, viz.:—All cities and towns situated at or near the sea, or at the mouths of rivers, collect the whole of the sewage of the district in a main drain, from which it is mostly allowed to find its way to the sea in the shortest direction, either in a constant stream, or intermittently, according to the position of the main sewer in regard to the sea level.

Towns situated on the higher reaches of a river used formerly to allow their sewage to run into the river itself, thus not only polluting the entire stream, and making it useless for alimentary

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purposes lower down, but also wasting all fertilizing matter contained in the sewage. The evils resulting from this state of things soon, however, proved so great in their effect upon the health of riparian populations, and in the destruction of fish, that an Act of Parliament was passed to put a stop to it. This Act, called the Rivers Pollution Prevention Act of 1876, does not actually prohibit the discharge of liquid sewage into rivers, but it insists upon the effluent liquid being highly purified, without either taste or smell, perfectly clear, and free from all organic and deleterious matter. This necessitated the application to the sewage of such towns of one or other of the various mechanical and chemical processes of sewage purification which had hitherto been used principally by the less favourably placed towns, situated far from sea or river. In these cases the sewage, as it issues from the main drain, is made use of for irrigating land, either by pumping or by gravitation; or it is chemically treated for the precipitation of the solid suspended matter, and for the deodorization of the whole. In some instances part of the sewage is treated by one method and part by the other, and in either case the resulting liquid, having been purified in accordance with the Act, is allowed to flow into the nearest stream or river. The question as to which of the above or other processes, either by themselves or in combination, should be used, must in each case, as pointed out by Mr. Robinson, be left to competent authority to decide, according to local conditions and circumstances in every one instance. In most cases where the necessary amount of suitable land can be had at a low rate, at a reasonable distance from the district which requires draining, the system of irrigation, either by mere surface application, or by the downward filtration system, or by both combined, appears to answer both in regard to efficiency and to expense.

But where such land is not to be had on reasonable terms, as happens in most of our great and densely populated centres of industry, recourse must be had to one or other of the various processes of chemical and mechanical treatment of the sewage.

In course of the discussion on Mr. Robinson's paper, which also referred to the Registrar-General's Health Returns and other matters bearing on the subject, and contained examples of the drainage systems of various towns, some interesting facts and data were elicited.

Amongst others, Mr. Baldwin Latham, Past-President of our Society, called attention to the researches of Dr. Maclagan, who had found by numerous experiments that, although sewage, if allowed to contaminate our water or food, gives rise to zymotic

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diseases, the sewage gases as they issue from the mouths of drains and traps, which had hitherto been debited with the same deleterious influence upon our health, are found to be innocent of such bad effects. If further experience should prove this to be a fact, a great difficulty will be removed from the consideration of proper house drainage, and will no doubt lead to further advance in that direction. It will, nevertheless, even in the supposed most favourable case, be wise not to rely too much upon the innocuity of sewer gases, which may probably act differently upon different constitutions, but to retain for our natural organs of smell and taste their proper functions of safeguards, ever on the alert against the insidious attacks of a penetrating and impalpable enemy.

I have now to refer to only two more papers, which complete the number of those read before us during the year, and are bracketed together because they are both in relation to a similar subject—that of mining. The first of the two in point of time was one prepared by myself, on "The New Pits and Hauling Machinery for the San Domingo Mines in Portugal"; the other was entitled "The Mineralogy of the Island of Sardinia," by Mr. C. J. Alford, who has been awarded the first premium of the year by the Council. The points to which I had the pleasure of calling your attention was the arrangement adopted for providing a new outlet for dispatching mineral from the workings in the mines, in addition to the three outlets already existing. These were a tunnel at an incline of about 1 in 20 leading to the open-cast work, served by small tank engines on a line of 3 feet 6 inches gauge, which bring the loaded trucks up to surface; the other two outlets consisted of two steep tunnels leading to the lower levels, at an incline, respectively, of about 1 in 4 and 1 in 7, through which tunnels the loaded trucks were pulled by means of hauling engines and ropes. For the purpose of attacking yet deeper levels, down to about 130 yards from the surface, a pair of vertical circular shafts were decided upon, each 11 feet diameter in the clear, fitted with cages, guides, heapsteads, &c., with special arrangements for enabling trucks to be raised from any intermediate level should that at any time become desirable. The cages are worked from a pair of coupled hauling engines geared to the drums, by means of flat steel ropes. The ore raised from these mines is what is called iron pyrites, being a bisulphide of iron containing, on an average, about 42 per cent. of iron, 48 per cent. of sulphur, from 1½ to 2 per cent. of copper, and a few other ingredients, amongst which arsenic, lead, small quantities of silver, and a trace of gold are the most important. Mr. Alford, in his interesting paper, described the several

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mining districts with which the Island of Sardinia seems to abound, but which, owing to the indifferent laws relating to mining property in that island, are not explored to anything like the extent that might otherwise be expected. There are ores of copper, lead, silver, antimony, zinc, and iron, besides argentiferous galena, and it is difficult to understand the policy of a Government which, rather than develop the resources of such a favoured spot, goes out of its way to throw difficulties in the path of the adventurer and of the capitalist. Even coal or lignite deposits are to be found there in the Valley of Gonnesa, and, though they are not of the same quality as ordinary gas and steam coal, they could no doubt be usefully employed in the reduction of at least some of the ores. Mr. Alford produced a geological map showing the various mining districts which he had described, and added to his paper a translation of the existing Sardinian mining laws. The principal iron ore mentioned by the author as included in those which he found on the island happens to be iron pyrites, the same as I have already mentioned as being raised at the San Domingo mines, and of a quality approaching thereto. In connection with the treatment of such ore, a new and very important invention has been brought to light within the last year, calculated to very materially alter and change the methods hitherto in use for its reduction. If even only a part of the expectations that are at present held out can be realised, it will bring about an entire revolution in the treatment of such ore and of its products, and I make therefore no apology for saying a few words about it.

I have already stated that iron pyrites may, generally speaking, be said to consist of about 42 per cent. of iron, 48 per cent. of sulphur, 2 per cent. of copper, and a few other component parts, from which it will be noted that it contains an extraordinary large amount of sulphur. Under the ordinary treatment, the ore is first flooded with water, which extracts a large part of the copper in the shape of a sulphate of copper or copper vitriol. The liquid so obtained is allowed to run through large settling tanks filled with scrap iron where a sulphate of iron is formed, and the copper deposited in the shape of a fine powder yielding about 60 per cent. of the pure metal. The ores themselves are put up in heaps, in which, through their affinity for the oxygen of the air, heat after a while develops itself, and they undergo a sort of natural roasting process without any external application of fuel. During this process, which takes many months to fully develop, the iron contained in the ore is changed into a ferric oxide whilst the sulphur is driven off, partly condensing on the surface of the heap, and in flues, and partly wasting in the

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shape of vapour, which poisons the air and kills vegetation for many miles around. The ores are also used by sulphuric acid manufacturers, who extract the sulphur for their purposes, the residue being again a ferric oxide, which in the trade is known as "burnt ore." Now, it occurred to Mr. John Hollway during some of his metallurgical investigations that, as bisulphide of iron can be made to burn in the open air, it might be possible to accelerate the above-described roasting process by driving air through the heated ore, and thus making the sulphur contained therein act as a veritable fuel, much the same as Mr., now Sir Henry Bessemer, makes use of the carbon contained in a charge of molten cast iron for converting the latter into steel. After making a number of preliminary experiments in the indicated direction, Mr. Hollway finally communicated the results of his ingenious reasoning to the metallurgical world by means of a paper read by him before the Society of Arts on the 12th of February last. He then explained that he first melted the ores in an ordinary cupola with coke in much the same manner as pig iron is treated, running the molten proto-sulphide of iron into an ordinary Bessemer converter. Here the charge was blown after a certain amount of sand had been thrown in, with a view to the protection of the lining of the converter. The resulting mass was emptied into moulds, where, after cooling, the metallic contents of the charge were found at the bottom, covered by a layer of slag, and with an intermediate zone, being a mixture of the two. The lower part or regulus was found by analysis to contain, on an average, about 46 per cent. of iron, 16 per cent. of copper, and 22 per cent. of sulphur, the rest of the sulphur having been partly burned and partly driven off together with the other ingredients. The copper found in the slag was not over ¼ per cent. In other experiments the proportion of copper found in the regulus was even greater than given above. The experiments were then carried still further, inasmuch as the preliminary melting of the ores in a cupola was dispensed with, the whole melting and converting process being carried on in one vessel, whilst provision was also made to catch and condense the sulphurous vapours given off during the melting of the charge. The result was the same, or rather an improvement, on the previous ones, thus clearly demonstrating the correctness of Mr. Hollway's conclusions.

The regulus obtained in this process, which in the latest experiments has been brought to contain as much as 30 per cent. of copper, is treated in an ordinary refinery for the extraction and separation of the metals. Thus the tedious and wasteful process of roasting the ores, which formerly took

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months to accomplish, and was even then carried out very imperfectly, whilst requiring a separate manipulation and appliances for the extraction of the copper, is by the new method capable of being completed in a comparatively short space of time. It can be carried on in a thoroughly scientific manner, with nice adjustments as to the composition of the resulting products, and does away with the necessity of heavy shipments of the raw material. Iron ore in the shape of a sulphate occurs in large quantities in very many parts of the earth, and by erecting a set of Mr. Hollway's reducing works on the spot, large sums of money will be saved in freight alone, and a new industry created where none has been before. The only fuel required is that for driving the blast engine, which in many situations may be worked by water power, whilst further developments and improvements, which we must look for with every new invention, may even lead to the use of the waste heat from the converting furnace for raising the necessary steam. The only question that may require further elucidation is that of the amount of sulphur which has to be sacrificed during the process, and the value of the metals that may be lost, either in the slag or through volatilization, in excess of the ordinary methods. Sulphur has a much higher marketable value per ton than ordinary coal that might be used for the reduction of the ores; and if it were found that the value so sacrificed would come to more than the cost of the coal, labour, and appliances hitherto used, the process may require some further development before it can be considered a commercial success. Nothing, however, can detract from the great beauty and ingenuity of the inception, and we can only wish it every success. Mr. Hollway informs me that a whole works, designed with the view of carrying out his process in its entirety, is at the present moment in course of erection at the mines near Maidanpeck, in Servia, and we can only hope that when these works have been put into regular working, Mr. Hollway will again bring the results obtained before the world by reading a Paper thereon, either here or before any other scientific body.

The past year has been distinguished also by the development of another metallurgical operation in connection with iron ore, viz. the production of steel direct from Cleveland ores, a process invented by Messrs. Thomas and Gilchrist, of London, and first put into practical operation on a commensurate scale by Messrs. Bolckow, Vaughan and Co., of Middlesbro', under the direct management of Mr. E. Windsor Richards. It is sufficiently well known that Cleveland iron ores, abundant and cheap though they are, have not hitherto been found suitable

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for the production of Bessemer steel, owing to the large amount of phosphorus (about 1·5 per cent.) which they contain; and where the manufacture of Bessemer steel is carried on, hæmatite ores, either native or foreign, have always had to be used, at a large difference in cost of the raw material. Many minds have been busy to find out a suitable remedy for the elimination of the phosphorus; one that should not only be efficacious, but also easily applicable, and sufficiently low in price to enable its use on a large scale. Two principal methods have been tried with this view. The one consisted in keeping the molten metal as it issued from the blast furnace, for a considerable time at a moderate temperature in contact with a slag, which, owing to its silicious nature, afforded the phosphorus contained in the iron an opportunity of combining with the silicates, thus leaving the metal comparatively pure. The molten metal was then brought into the Bessemer converter, and treated in the ordinary manner. The name principally connected with the investigation of this matter is that of Mr. Lowthian Bell, of the Erimus Ironworks; but I am not enabled to say how far it has been found to answer on a practical scale, owing to difficulties which we may hope to be overcome at a future time. For the present, at least, it has been put rather in the background by the development of the second method—that of Messrs. Thomas and Gilchrist's—the principal feature of which consists in the introduction into the Bessemer converter of a new basic lining and fluxes, capable at the same time of resisting the high temperature in the converter, and of assisting the extraction of the phosphorus. In the ordinary Bessemer process, the oxygen of the air which is blown through the molten iron combines chemically with the carbon and some of the iron, and thereby raises the temperature of the whole, whilst some of it at the same time reduces the iron silicates and the silicious lining of the converter, with which it forms silicious acid. This acid combines with the sulphur and most other impurities contained in the iron, forming a slag during the operation, whilst the iron itself is cleared of those impurities. The excess of carbon in the iron is reduced to a carbonic oxide, which burns at the mouth of the converter into carbonic acid, giving rise to the beautiful coloured flame issuing therefrom. When a certain quantity of the superfluous carbon has thus been removed, which is shown by a change in the colour of the flame, the metal is no longer iron but steel, and is then ready for casting into ingots. All ordinary impurities originally contained in the mass are thus got rid of at one operation, with the exception of the phosphorus, the affinity of which for the iron is greater

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than for any of the other materials with which it is brought into contact.

Now it occurred to Mr. Sidney G. Thomas and Mr. Gilchrist, that by lining the converter with a material which, when forming a slag, should have greater affinity for the nascent phosphorus than the iron has, it would induce such phosphorus to combine with the constituents of the lining, and leave the iron free. Such a material would for instance be found in magnesian limestone, which abounds in the vicinity of many iron mines, and would, therefore, not be costly to procure. The same idea, it should be stated, had also occurred to others, both before and concurrently with Messrs. Thomas and Gilchrist. Notably, Mons. Tessie-du-Motay, at Commine, in France, had experimented in that direction as far back as 1871, whilst Dr. Siemens, Mr. Snelus, and others had also attacked the subject from the same point of view. But the difficulty had always been that a lime lining used in that way in the converter had been so rapidly destroyed, partly through the very chemical interaction which it was intended for, and partly through the heat and through abrasion, that it was generally either entirely destroyed before the operation was completed, or so much damaged as to necessitate serious and expensive repairs after each blow. The great step in advance, with which Messrs. Thomas and Gilchrist must be credited, is that they made use of the suitable material in two forms—the one hard and indestructible, even at a high heat, forming a sound and lasting lining, and the other easily convertible during the blow into the desired basic slag. For the lining they employ a magnesian lime brick, containing about 90 per cent. of lime and alumina, and only some 6 to 8 per cent. of silica, with about 2 per cent. of iron. These are moulded and pressed, and burned in a kiln at a specially high temperature before they are built into the converter, and are found to stand the operation remarkably well, whilst limestone of the same chemical composition is used in its ordinary state as a fluxing material for producing the basic slag. If the same fluxing material had been used in an ordinary Ganister lining, the latter would not only have been destroyed, but by its affinity for the magnesian lime, have prevented the latter from combining with the phosphorus.

Thus, in the new method, the chemical action and reaction of the various materials upon each other has been perfectly secured, and the only question now to consider is that of cost. Respecting this, Mr. Thomas has kindly supplied me with a few data which set the question at rest, and which, as I believe they have not been published before, it may interest you to

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learn. It appears that Mr. Thomas's basic magnesian lime-bricks are now sold at from 5*l.* to 6*l.* per 1000, from 3000 to 4500 being necessary for lining a converter, according to size. The whole cost of lining, say an 8-ton converter, labour included, ranges from 30*l.* to 40*l.*, and lasts for from 75 to 120 blows at present, whilst with increased experience it is expected to stand at least 200 blowings. Assuming a mean life of 90 blows, which would produce about 700 tons of steel, and allowing a large margin for contingencies, the maximum cost of the lining per ton of steel may be taken at 2*s.* 6*d.*; add to this for the fluxing lime 2*s.* per ton of steel, and 3*d.* per ton for the labour of four extra men employed about the converter, will bring the extra cost of the process, beyond the ordinary Bessemer operation, to 4*s.* 9*d.*, or, say in round numbers, 5*s.* per ton of steel produced. This does not take into account the saving in spiegeleisen, nor the value of the phosphoric slag. Now it takes 1·13 ton of ordinary Bessemer hæmatite pig to make one ton of steel, which, at the prices in vogue at the beginning of the present year, would cost, delivered at Sheffield, 113*s.*; and, reckoning 1·17 ton of Cleveland pig to produce the same amount of steel, the cost of that delivered at Middlesbro' at the same date amounted to 58*s.* 6*d.* Add to this the 5*s.* as the extra cost of the new process, and we have 63*s.* 6*d.* against 113*s.*, leaving a difference of 52*s.* 6*d.* in favour of the new process; or, again taking round numbers, we find an advantage of 50*s.* per ton of steel. At the present time, when prices have risen beyond those stated above, the difference is still more marked, and it will be noticed that the great advantage arises through the use of the cheaper pig iron. So that the relative value of the pig iron must change very greatly indeed before Cleveland need have any fear of competition. The only slight difficulty which Mr. Thomas refers to is, that the present Bessemer plant is not quite so suitable for carrying out the new process as it is for the old one, and that when the plant has been altered to meet the new requirements (which he estimates at a cost of about 1000*l.* for each pit) these slight difficulties will disappear, and will probably reduce the extra cost to less than 3*s.* per ton. There are at this moment thirteen converters running under Mr. Thomas's licence in England and on the Continent, and several entirely new plants are being put up in addition, so that the practical success of the whole may be taken as assured. The changes which by this new departure may be brought about in the extended use of steel are portentous, almost as great as was the case when the original Bessemer process, of which this is a development, was introduced. Iron

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rails for railway uses have long been doomed—their fate may now be considered sealed—ship-plates, boiler-plates, joints and girders, wire, bridge bars, and in fact all purposes for which large quantities of materials of similar sections are employed, can now be served by a material both better and cheaper than iron. What this means a simple set of figures will show. It has been computed that the present annual output of iron ore in the United Kingdom is 17,000,000 of tons, whereof only 2,000,000 is hæmatite ore, whilst 15,000,000 consist almost entirely of phosphoretic ores, which hitherto could not be used for the production of steel. All this large quantity is now liberated for use in that direction, and is calculated more than any other cause to contribute to the resuscitation of our iron and steel industries, which had been so grievously depressed during recent years.

It behoves us, however, not to be too sanguine on this head, not "to rest and be thankful," not to relax our efforts in the investigation and improvement of the new process, or in the creation of new works in other directions. For by a strange coincidence the new departure in the steel trade, which we have just been considering, is by no means likely for any length of time to benefit this country exclusively. Phosphoretic iron ores abound in many countries of the world, such as Germany, France, America, Belgium, and others. Owing to their previous inapplicability to steel making, these ores have been mostly lying dormant, and will now through the new process be generally thrown upon the market, as the nations to whom they belong are reckoned among the most industrious of the world. Thus whilst England on the one hand will produce much more steel and more cheaply than before, not only may there be a smaller number of customers, but a formidable competition will be created in markets where none was found before. Let us hope that the perseverance and inventive genius of our great industries will get us over this prospective difficulty, as it has so often been able to do before.

Having now finished the record of papers read before our Society during the past year, and of a few external matters closely connected with them, I now come to a subject which is sure of your favourable reception, as being very popular amongst us, I mean the vacation visits. These visits, which take place during the summer time, when the more serious business of our Society is in abeyance, may be considered quite a special feature of our body, and I believe I am right in stating that we were the first of any professional or scientific societies to institute such outings as a regular part of our annual programme.

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They were instituted principally with the object of giving our Members an opportunity of gaining experience on the spot, by the inspection of important works in the various stages of progress towards completion, and they incidentally serve to gather the Members and their friends in a pleasant and sociable way, and to keep up our mutual intercourse at a time when otherwise, through the periodical cessation of our meetings, we should have been entirely separated. Many pleasant incidents are associated with these gatherings, not the least pleasant being the fact of the very cordial and courteous reception we are invariably receiving at the hands of those to whom our visits are made. Very few important or interesting works and places within the metropolis and in its neighbourhood have been denied a visit from our Society, or will be so in the future, and in this way we have been enabled collectively to see and learn a great many things, that to any individual by himself, would have remained a closed book. At all the visits during the past year there has been a fair attendance of Members and their friends, who readily followed the call and guidance of my genial predecessor, showing that great interest is taken in the success of these meetings, which I hope may continue further to develop from year to year.

The first of our outings, which took place on the 24th of June, 1879, was devoted to the visit of two places, one being the Providence Ironworks, Millwall, the property of Messrs. Samuel Cutler and Sons, the other being the Millwall Docks in the immediate neighbourhood. Through the ironworks we were conducted by the Messrs. Cutler themselves, both Members of our Society, one of them on the Council, and we had there an opportunity of seeing several gasholders and tanks in various stages of completion, more particularly a telescopic gasholder 122 feet in diameter, and in two lifts of 32 feet each, intended for the town of Ipswich. We also saw various tools and appliances specially designed with the view to facilitating and expediting the work carried on at the place, such as multiple punching machines, direct-acting steam saws, and other matters.

Through the Millwall Docks we were led by the Dock Company's Engineer, Mr. F. E. Duckham, who is also a member of the Council of our Society, and who made us acquainted with the various arrangements and appliances of that extensive place. He explained the ramifications of the system of hydraulic power which is made use of in many ways, such as for the working of the dock gates, the capstans, cranes, &c., and after conducting us to the pumping engines for emptying the dry docks, the engines for working the hydraulic machinery, showing

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his portable hydrostatic weighing machine, and other interesting matters, Mr. Duckham finally introduced us to the latest production of his inventive skill, the "pneumatic dredger." With this apparatus, steam and compressed air are made use of for dredging and discharging soil from the bottom of a dock or river at a great saving of time and expense.

The dredging is done by means of bucket ladders in the usual way, but the soil, instead of being delivered into open barges, is dropped into cylindrical vessels which, when full, are hermetically sealed, except one inlet for compressed air at the top, and a large outlet for the dredged material at the bottom. Pipes are connected with the outlet; on the air-pumps being put to work, the material is conveyed to a distance of as much as 150 yards if desired, without any further labour. The dredger was shown in operation during our visit, discharging at the rate of about 200 tons in sixteen minutes, the whole cost of the operation being so small, that the saving effected by the Dock Company has been found sufficient to pay for the whole expense of the apparatus and appliances in less than three years working.

On the same day we further saw two of Messrs. Jordan's patent hand-power rock drills at work, doing great execution on some hard granite, and also had an opportunity of witnessing the action of Messrs. Priestman's self-acting skip for lifting grain in bulk out of barges and vessels. Our visit was brought to a conclusion by the inspection of the ironclad corvette 'Orion,' built by Messrs. Samuda Brothers, and then being fitted out by them in the Millwall Docks. The 'Orion' was to have engines of 600 nominal and 3900 indicated horse-power, to be built by Messrs. Maudslay, Sons, and Field, for driving twin screws, engines which, when completed, will no doubt be equal to what may be expected from the reputation of that firm.

In the middle of the day the Messrs. Samuel Cutler and Mr. Duckham had provided for us, in the local club hall, an excellent luncheon to which we all did ample justice, and the day was wound up as is our invariable custom on visiting days, by our Members and their friends dining together in the evening.

The next vacation visit which I shall have to refer to, is that which we made to the Victoria Docks Extension Works, by permission of the London and St. Katharine's Dock Company.

Members of our Society will not need to be reminded that we had visited the same works which had been in progress of construction for several years, on various previous occasions, the present being, I believe, our fourth visit. They comprise a

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large addition to the dock accommodation hitherto afforded by the Company, and entailed in their execution some very heavy engineering work, principally in the shape of excavations for no less than 80 acres of additional water area, in building the extensive length of dock walls entirely of concrete, and in forming a tunnel under the floor of the dock for accommodating the North Woolwich Branch of the Great Eastern Railway, which hitherto ran across the space now given to ships and shipping. The appliances used for carrying on works of such magnitude were commensurate with the importance of those works. On our first visit, excavating and making trenches was the order of the day, and accordingly we then saw in operation every possible appliance that could economically be used for that purpose, from the navvy, if I am permitted to call him an appliance, with pick and shovel, and wheelbarrow, to the powerful steam excavator, removing at one swoop a whole slice from top to bottom of a deep cutting. These were aided by horses and carts as well as by many hundreds of railway trucks and several locomotive engines, for the removal of the excavated materials. Pumping engines were in operation in various parts to keep the works dry, whilst concrete mixers, stone and timber sawing machinery, and a variety of other appliances and apparatus were also kept constantly at work, to save time and to facilitate and cheapen the cost of labour. On our last visit the whole of the works had been nearly completed, trains had been running for many months regularly through the sunk tunnel (which is as fine a piece of brickwork as can be seen anywhere, carrying the rail level 40 feet below its original elevation); the whole extensive floor of the new dock had been completely excavated, a large and a small graving dock for the repair of vessels had been built by the side of the wet dock, all the heavy concrete walls around this latter had been completed, as well as a strong double timber jetty into the Thames, for the protection of the entrance. The entrance lock, which is of magnificent dimensions, is built entirely in brick with stone facings, the bottom is formed of a brick invert on concrete, and it is fitted with two pairs of gates, which were just being put in place at the time of our visit. The lock gates are of iron, and of somewhat special construction, the supporting rollers being placed in such a position that a straight line drawn through their centres and that of the heel post would run through a line plumbed from the centre of gravity of the gate itself, calculated to ease the working of the gate and to prevent its distortion. The opening covered by these gates is 80 feet across at the lower part, with 33 feet of water over the sill at high tide.

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On the day of our visit the "Wet" Dock did not belie its name. Torrents of rain, for which many of us were hardly prepared, as the sun had shone out brightly in the morning, came down on our devoted heads. But this did not prevent our persevering in the thorough examination of everything worth seeing under the guidance of Mr. A. C. Andros, the resident engineer (on behalf of Mr. A. M. Rendel, the engineer of the docks), and of Mr. W. Colson, the engineer of Messrs. Lucas and Aird, the contractors, to whom we also were indebted for our luncheon, and the means to counteract the dissolving influences of the weather. On that day we had, for the first time in my experience, to forego the pleasure of meeting again in the evening, as we dare not tarry in our clothes, which had got wet right through, and we returned from the excursion too late to admit of changing them at a reasonable hour. I may add that the official opening of the new dock is expected to take place by about the middle of the present year, and its effect will be to greatly relieve the traffic on the river at a point where navigation has hitherto frequently been very dangerous.

The next of our visits to which I will claim your attention, and which was in reality the second in point of time, was paid to the Telegraph Cable Works of Messrs. Siemens Brothers, at Charlton, by permission of the proprietors. Dr. Charles W. Siemens, D.C.L. and F.R.S., Member of the Institution of Civil Engineers, and an Honorary Member of our Society, was himself present to receive us, and had on this special occasion kindly thrown the whole of his extensive works open for our inspection. In these works everything connected with telegraph cables and electric apparatus is produced and manufactured from the very commencement, all under one management though separated into departments, under the very eyes and direct inspiration of the principals, aided by a competent staff and a complete system of testing the quality of every article in its various stages towards completion. We were there shown how the guttapercha used for covering the copper cores of submarine cables, from the native state in which it arrives at the works, is taken to be macerated, washed, steamed, pressed, strained, kneaded, and rolled an innumerable number of times until it becomes of such purity and pliability as to satisfactorily stand the high insulating and other tests to which it is subjected before being taken to the covering machines. Indiarubber is treated in a similar manner, though the process differs in many respects from the previous one to suit the properties of the material. There is apparatus for testing

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copper wire upon its conductivity, and iron wire upon its strength; apparatus for making and covering electric cables of every size and construction, the whole so arranged that the finished cable as it issues from the machines is coiled into enormous tanks on the premises, where it remains until required for shipment; or it may at once be led into the tanks of the splendid cable ships owned by the Company to be immediately forwarded to any distant part of the world. Besides the cables, the Company also manufacture all and every part of the appliances used for sending and receiving telegraphic messages, of which we were shown a fine collection in the model room.

Intimately connected with the above, though forming a separate manufacturing branch, is the department for the production of magneto-electric machines and apparatus, principally for those with which the name of Messrs. Siemens is so intimately associated. These machines, in which a powerful electric current is created by means of the rotation of copper coils within the extremities of curved induction magnets, are produced in various sizes and shapes both for the production of continuous and for alternating currents. They are used for a variety of purposes in the technical arts, but their most prominent application of late has been in connection with the electric light, for lighthouses, and for general illumination. The lamps for this purpose are also made at the same works, and we had an opportunity of judging of the excellence of several varieties of the improved Siemens lamp both singly and in groups. Every small detail of these again, down to the very carbon pencils, is made entirely on the works, and in the various testing rooms special arrangements are made with the view to trying and practically ascertaining the value of every new and promising invention that may be brought before the world in that direction. It would lead me too far and would be foreign to my purpose, were I to give a full description of all that we saw in those interesting works, but I cannot refrain from stating that the whole made the impression of a vast and carefully thought-out system of manufacture, carried on under the direction of a master mind, its very appearance of rest and quietude inseparably connecting itself with the idea of magnitude and power. On the day of our visit the cableship 'Faraday' was moored in the river in front of the works, taking in the cable which was then manufactured and nearly all completed for connecting France with the United States by direct electric communication. For this cable, which was to be laid between Brest and New York, a task which has since been satisfactorily completed, the enormous tanks on board the

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'Faraday' offered ample space without encroaching on the accommodation for officers and crew of the vessel. The saloon had been specially and gracefully prepared for our reception, and a sumptuous luncheon provided, and at one of the two parties into which our very numerous company had to be divided, Dr. Siemens himself, to our great gratification, took the chair and bid us welcome. In the evening, our kind host of the morning added further to our obligations by gracing our quiet and friendly dinner with his presence, and thus ended a very pleasant and instructive day.

During the past year, in addition to the cable mentioned above, a few others of great importance have been laid, that of most interest for this country being the one which opened direct communication with the South African colonies, and which it may be noted *en passant*, was not laid one moment too soon. The connection with the general European and Asiatic telegraph system was made at Durban, whence the cable was taken to Aden, on the East Coast of Africa, down to Zanzibar, touching at several intermediate points. Some of the Australian and New Zealand telegraph cables were duplicated during the year, whilst additional accommodation was also given in several other directions, so that the last year must be credited with a fair amount of progress in that respect.

The same cannot be said in regard to inventions respecting the application of electricity to lighting purposes. Experiments have been continued during the year on a somewhat large scale, with general improvements in the various apparatus and lamps previously employed, but without producing any startling novelty, and even Mr. Edison's latest improvements in the incandescent electric lamp, whether by the use of platinum and iridium or by that of carbonized cardboard in vacuo, appear as yet to fall short of what we were led to expect. There are, however, so many clear-headed and practical men now at work on this problem, aided by the pronounced opinions of those most advanced in science who fully believe in the ultimate success of the electric light, that we must be prepared any day to hear that the problem has been solved. That the general use of gas should, however, sensibly diminish when that event takes place, I am by no means ready to believe, since there remain a great many fields yet unexplored for the adaptation of gas, even if gas lamps were entirely done away with; and I shall not at all be surprised to hear that gas can even be employed to form the electrodes of an electric lamp in place of the solid carbon pencils now in use.

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The most novel and ingenious invention in connection with electric apparatus, which the last year has brought forth, is no doubt that of the writing telegraph by Mr. E. A. Cowper, M.I.C.E., President of the I.M.E., &c. By this invention the message written down on a moving slip of paper at the sending office, is reproduced on a slip of paper in the receiving office the very facsimile of the handwriting of the sender. The sending pencil is connected by slight rods at right angles to each other in plan, with two sets of resistance coils through which a current passes, the connection being made in such a way that by the movement of the pencil a current of varying strength is sent through either of the two sets of coils, and is led to two other sets placed at the receiving station. The coils at the latter station incite electro-magnets, which carry two armatures also placed at right angles to each other, and connected by light rods to the receiving pen, guiding its motion in the two directions in accord with the strength of the current received by each of the coils. The receiving pen thus moves in entire unison with the sending pencil. Considering the difficulties which had to be overcome at every step in the construction of such a sensitive apparatus, it must be pronounced a great success. The action is perfect; several railway lines are already using it, and we may hope to see its application rapidly extending.

The last visit made by the Members of our Society during the past year was to the Patent Stone Works of Messrs. A. H. Bateman and Co. at East Greenwich, works which we had previously inspected in the year 1872, and which have been improved and enlarged since then. A description of the process carried on at those works will be found in our 'Transactions' for 1873, in the Address delivered by our late lamented friend, Mr. Jabez Church, sen., the then President of our Society, and I need not therefore refer further to it here, beyond saying that the mixture of dissolved flint and sand is employed in various proportions by itself or with other ingredients, to produce artificial stone of great lasting powers and for a large variety of purposes. One of these is that for use as grindstones, the manufacture of which and that of the kindred emery wheels constitutes a special branch of the business. Tools fitted with grindstones, for the production of every kind of surface on metallic objects, are now made of such variety and with such precision, that they have taken the place of many of the usual machine tools in engineering works. They save a large outlay in time and labour, and, as work can also be finished very accurately by their use, their adaptation is a

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move in the right direction. Another object of special interest shown us at Messrs. Bateman's works was a steam engine, stated to have run for the last eighteen months without the application of any lubricant to any of the bearings, these being all bushed with a material called metaline, for the manufacture of which Messrs. Bateman hold a licence. The substance has a metallic look, somewhat darker than the colour of lead, and a greasy touch, and the bearings seem to wear thoroughly well, and to keep quite cool. Our Members were very hospitably received at the works, and we were thoroughly well pleased with a visit which had added considerably to the store of our practical knowledge in a direction differing greatly from that of our visits previously described.

I have now completed the record of our papers and vacation visits during the last year, as well as of a few outside subjects bearing thereon, and trust to have made good the proposition stated at the beginning, viz. that by keeping well up with the engineering problems of the day our Society honourably and usefully occupies the position which it has decided for itself to fill. As such I commend it to your best care and attention, and particularly enjoin you to endeavour to add to its numbers. Our Society, more especially during the last five or six years, has had much uphill work, and has found some difficulty to maintain its status. One or two important institutions who had their origin in the country have lately immigrated into London; others have lowered and widened their conditions so as to enrol a greater number, especially of the younger Members, who would otherwise, as a matter of course, have joined us. Again, the times have lately been very bad for the profession at large, and as many of our Members are either young beginners on their own account or assistants to other Engineers, they would be the first to be affected by a scarcity of work, and thus be unable to keep up subscriptions. Not the least of the difficulties which we have had to contend against during the last year was the resignation of our excellent Secretary, Mr. Perry Fairfax Nursey, so long our "guide, philosopher, and friend," on his accepting a commanding and honourable position in a new sphere of action. The excellent qualities of that gentleman are so well known that I need not dwell upon them at length. Suffice it to say that the estimation in which he is held by all of us was shown by the liberal response made to the appeal of the Council for a testimonial to him, which enabled our late President to present him with a piece of plate and a purse containing about 150 guineas as a slight token of our regard and esteem. The presentation took place on the occasion of

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our annual dinner, on the 17th of December, 1879. You may readily believe that it was no easy task to find a gentleman with the proper qualifications to succeed our late Secretary—one who, whilst suiting our own requirements, would also find the Secretary's work and position to his own taste.

We believe now to have succeeded in obtaining the services of such a gentleman in the person of Mr. Alfred Elgar, formerly Assistant-Secretary to the Institution of Naval Architects, who comes to us with very strong recommendations. During the few weeks that he has been with us he has already managed to get most of the threads of the Society's business into his hands, and we have every reason to think that he is worthy of our full confidence. The best advice which I can give him is that he may try to follow as near as may be in the footsteps of Mr. P. F. Nursey, a task which will be facilitated through the latter having accepted the position as Member of Council for the current year, so that we shall have the full advantage of his presence and advice. I cannot refrain here from stating that the warmest thanks of our Society are due to our Honorary Secretary, Mr. Alfred Williams, who, during the short interregnum which followed the resignation of our late Secretary, took upon himself, aided by your late President and the Members of Council, most of the routine work of the business of our Society, so that no break occurred in its continuity.

For the reasons given before, and through a variety of other causes, our Society, as already stated, has had some uphill work during the past few years, which induced your Council a short time ago to instruct an accountant of high standing in the City of London to carefully examine into the whole of our assets and liabilities for the two last years, and report to us thereon. The statement for 1878 has been sent in by that gentleman, and shows a reasonable excess of assets over liabilities, and we expect last year's statement to be fully equal to the preceding one in that respect. As we also have a respectable balance at our bankers to meet current expenses, we must consider the position of the Society so far satisfactory. At the same time we must not blind ourselves to the fact that for some years past your Council have occasionally felt anxious as to their ability of making both ends meet. With the revival of the general business and commerce of the country, which I am happy to say has set in with full force, and has all the appearance of being of a permanent character, I live in hopes that our position in that respect will soon change for the better, and will steadily improve. We must not forget that a Society like ours is not a commercial undertaking, in which the subscribed capital can

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be made to yield a profit or increase. The only direction in which your Council can work is to endeavour to keep expenses as low as is compatible with the efficient working of the Society. Whenever the amount of the subscriptions received from Members gets too close down to that minimum expenditure financial anxieties are likely to arise, and this is one of the reasons why I wish to impress upon your minds the necessity there is for adding to our numbers. We count at present from 360 to 370 Members of all classes, and if only half of them would make up their minds each to procure one new accession to our numbers during the year, we should at once obtain such an increase as would be calculated to lift us permanently above any liability to financial difficulties. I am sanguine enough to think that you will all make an effort to get us, during the current year, into that desirable position.

Gentlemen, my address has attained to so much greater length than I had expected, that I much regret the time at disposal will not allow me to refer to several other subjects which I had intended to touch upon, even if I had not already made too great a demand upon your patience. I hoped to be able to make a few remarks on the St. Gothard Tunnel, now so nearly pierced through, and the completion of which its great contractor, the late Mr. L. Favre, was not destined to witness. I hoped to refer to the lives of several of our late fellow-labourers in professional and scientific work, who had been taken from us during the past year. I had intended to examine into several of the disastrous accidents that took place during the same time, more particularly that of the bursting of a 38-ton gun on board of H. M. ship 'Thunderer,' which happened in the first week of the past year, and in that of the terrible catastrophe, the overthrow of the Tay Bridge by a heavy gale of wind, which occurred in the last week of that year. And last, though not least, I had wished to say something on engineering education, a subject which, owing to the great steps in advance made of late years by science, is becoming of increased importance every day.

All these and other matters I must abandon for the present, but I may perhaps, in conclusion, crave permission, in reference to the subject of education, to transfer to these pages a saying of the late Professor Redtenbacher, of the Engineering School at Carlsruhe, which will bear repetition. I should premise that Professor Redtenbacher, some twenty to twenty-five years ago, held very much the same position in Germany that the late Professor W. M. Rankine held in this country. He had

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been an engineer in large practice before he obtained the professorial chair at the Polytechnicum, where he was ultimately raised to the Directorship, a post at present occupied by our Honorary Member, Dr. Grasshoff. Redtenbacher's labours were recognized far beyond the confines of Germany, and he was always very anxious to impart to his pupils those fixed and clear principles of mechanics which were afterwards to form their guide and standard during their professional career. His motto may be rendered into English thus:—"The general principles of mechanics constitute the only true and lasting basis not only for engineering science, but for the whole vast realm of sciences penetrating into the mysteries of nature." Or, in other words, nothing can be undertaken in this world of ours, no action or reaction can take place, which cannot finally be reduced to a mechanical problem; and whether a science is called physics or chemistry, whether we combine or dissolve bodies, whether it is a question of heat or light or electricity, whether we consider the motion and interaction of the stars, the movements of the winds and of the waves, the growing of plants, and even the descent and evolution of man, the more nearly the explanation of a natural phenomenon approaches a mechanical solution, the more accurate such explanation is likely to be. And as it is the Engineer, in the widest sense of that term, who will ultimately have to deal with every natural phenomenon in one form or another, in his endeavour "to make the forces of nature subservient to the uses of man," it is the young Engineer to whom the key of the whole situation must be given by inculcating him at the very commencement with sound principles of mechanics.

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March 1*st*, 1880.

JOSEPH BERNAYS, PRESIDENT, IN THE CHAIR.

THE UTILISATION OF COAL SLACK* IN THE MANUFACTURE OF COKE FOR SMELTING.

By G. M. WARD.

In the early days of coking slack little attention was paid to its purification, either before or during the coking process. The cardinal idea which then prevailed was that the coking of the slack was simply to conglomerate its particles, and so utilise and put into a marketable form refuse small coal which would otherwise have to be thrown away. The advance of science has caused considerable attention in recent years to be paid to the production of a pure, dense, strong coke; and much skill and ingenuity have been applied to the construction of machines for the efficient separation of shale, pyrites, and other solid impurities from the slack, prior to its being coked; also to the construction of ovens for the perfect and economical expulsion of the volatile matter. To attempt a description in detail of all the various designs of coal-washing machine and coke oven, would be beyond the scope of the present paper; the writer will therefore confine himself to the description of a few machines and ovens illustrating the rationale of coal washing and coking, and the economic principles which obtain therein.

Before doing so, however, he will make a few brief remarks upon coal washing and coking generally.

As in metallurgical operations the value of a fuel, so far as its heat producing power is concerned, is in proportion to the degree of heat it is capable of generating, and as the capability of carbon to produce an intense and concentrated heat is in proportion to its freedom from ash and volatile substances, it is desirable to reduce the former to a minimum and effect the perfect expulsion of the latter.

* Or small refuse and other comparatively valueless coal, which is acquired by the miner when "heading," containing shale, &c., of which thousands of tons lie unproductive in many of our colliery districts.

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It is important that the coal should be coked at a high and uniform temperature, as with respect to the hydro-carbons—of which coal principally consists—the effect of increasing the temperature of the coking process is to prevent the hydrogen carrying off so large a quantity of carbon as it otherwise would, the union of hydrogen with carbon being dissolved by heat with a *rapidity* and *completeness* proportionate to its intensity.

There is thereby greater yield in coke—the quantity of carbon carried off by the hydrogen being in inverse ratio to the temperature of the oven. Furthermore, a high temperature tends to bake the coal harder, which will presently be further alluded to. One of the objects in separating the shale and other foreign solid substances from the slack, is to facilitate the attainment of a high temperature in the oven, and thereby the proper coking of the coal, as these substances act mechanically in obstructing the evolution of the gases, upon which the heat of the oven depends, as well as the crystallisation of the coke. It is however desirable to separate the shale and other earthy matter contained in the slack, as perfectly as possible, for several reasons besides the one just alluded to.

(1) The shale,* &c., increase the percentage of ash, which seriously affects the calorific value of the coke; for instance, if 1 kilogramme of coke contain ·92 kilogramme of carbon, and 1 kilogramme of another quality of coke ·72 kilogramme, the calorific value of the former will be 7360 units of heat Centigrade, against 5760 in the case of the latter.†

(2) These substances also of course increase the quantity of slag. There is, however, silica in coal—derived from its organic origin—which enters so minutely into its composition as to be inseparable by mechanical means, and of course is not removable in the coking process. But one of the objects in producing a fuel of the highest pyrometric effect is to facilitate the fluxing of its ashes, and so render innoxious the silica contained in it; by preventing the silicon becoming alloyed with the iron, the tendency of it being to render iron brittle and difficult to puddle. Of course silicon in pig is traceable to the ore as well as the fuel, but the writer is referring to the fuel only. The constituents of fuel on which its calorific powers depend are carbon and hydrogen, but the more carbon a fuel contains, the greater is the degree of heat which it is capable of producing, for carbon burned in contact with air

* The specific gravity of shale may be taken at 2·6 as against 1·20 to 1·59 in the case of coal.

† 1 kilogramme of carbon develops, when burnt to CO_2, 8000 calories.

$8000 \times \cdot 92 = 7360$

$8000 \times \cdot 72 = 5760$

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to carbonic-dioxide will produce a heat of 2558° C., whilst hydrogen burning to water produces only 2080°: from which is gathered that the greatest pyrometric effect is obtainable from pure carbon. The nearer therefore coke approaches pure carbon the greater will be its pyrometric power.

With respect to sulphur, sulphur exists in coal as pyrites. It is also found in some coals as sulphate of calcium; and occasionally it is found as sulphate of barium; but as sulphates of the alkaline earths may exist in considerable quantity in the blast furnace without having any effect upon the quality of the iron, it is desirable, in valuing any fuel, not only to know what the percentage of sulphur is, but in what form the sulphur exists. The most prejudicial form in which it occurs in coke is sulphide of iron, for sulphur in the pig is attributed to sulphide of iron in the fuel, or in the ore. In the coking process part of the sulphur in the pyrites is evolved, and passes off along with the volatile matter in the form of sulphur compounds, but about a quarter to one half is retained in the form of sulphide of iron. The tendency of sulphur is of course to make iron white; cause it to be brittle when cold; and impart to it a pasty condition which impairs its ductility when hot.

Pyrites are largely separable from the slack in the coal-washing machine, their specific gravity being, in their pure state, 4·8 to 5·1, as against 1·20 to 1·59 in the case of coal. The sulphur is further reduced to a minimum by watering the coke at the highest temperature immediately after the coking process is completed. If the coke is drawn red hot and water poured upon it, the evolution of sulphuretted hydrogen is perceptible in the steam. It is desirable, however, to continue the use of the hose after the heat has ceased to be sufficient to convert the water into steam, as there remains in the coke sulphur in a state capable of being washed out.

Here it may be observed that coke which has been condemned as too sulphurous to be used for smelting, has after exposure to the weather for several years been used with satisfactory results. The sulphide of iron which it had previously contained having gradually become oxidated and washed out by the weather.

In passing, the writer may just remark the corroding action which sulphur has upon iron and copper, and that when sulphurous coals are continually burnt under a boiler, the plates are rapidly deteriorated and the boiler rendered useless.

With respect to a high temperature in the oven baking the coal harder, this is not to be confounded with that "hardening" which is apt to occur in coking bituminous coals, which consists in a rounding of the edges of the crystals, a blocking up of the

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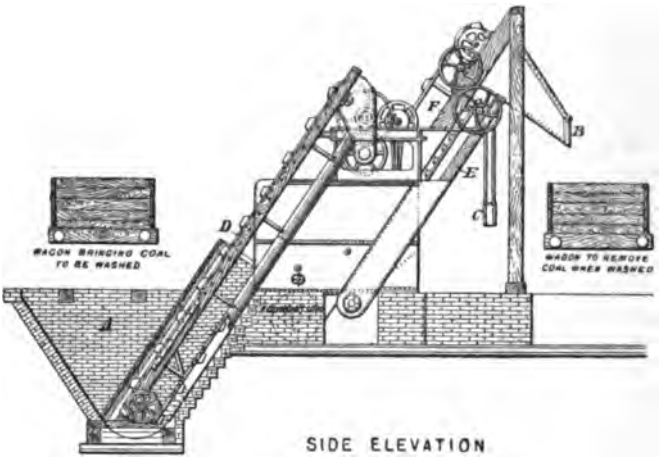
pores, and a general hardening and toughening of the coke, rendering it incapable of giving out an intense and concentrated heat, owing to it presenting less surface of contact to the oxygen of the atmosphere, and this is occasioned by allowing the coal to remain in the oven too long.

Besides the tests of purity and porosity there are the tests of density and hardness. In high furnaces, owing to the great height and consequent weight of the column of materials, they become so compressed that the coke must be of the hardest and strongest kind, to enable it to bear the burden.

Density is obtained by reducing the coal to small and equal particles by crushing (which should be done after the coal is washed); and hardness, as has been previously remarked, by exposing the coal to a high temperature in the oven.

Fig. 1 shows the general arrangement of Sheppard's Coal-washing Machine.

FIG. 1.



Unwashed coal is delivered by waggon into a hopper, whence it is raised by an elevator, by which it is delivered into the bosh.

Fig. 2 represents a section of the bosh, showing the way in which the solid impurities are separated from the coal. The separation is effected by agitation of the slack in water, by which agitation the various substances arrange themselves in layers, according to their specific gravity—the coal, which is the lightest substance, forming the uppermost layer, and the heavier substances, which are the solid impurities, forming the

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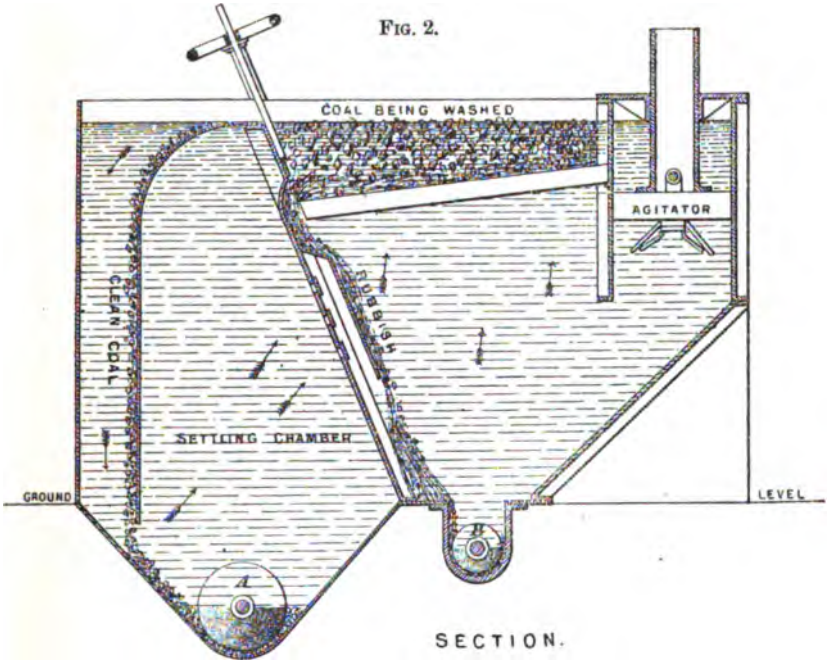
lower layers. The slack is deposited on a grid, through which the pulsations are given. The pulsations are produced by means of a plunger, operating in a compartment at one side of the bosh, and the machine is so constructed that they shall not only separate the substances into layers, as above described, but gradually remove the pure coal into a separate compartment, and likewise the shale and other impurities into another compartment. Besides that law which causes the substances to separate into layers according to their specific gravities, there is

FIG. 2.



another law which is brought into operation in coal washing. The slack is delivered into the bosh vertically, at one side of it, viz., at the side opposite to the overflow plate, and the current, in the direction of the latter, tends to separate particles of coal from the slack, as soon as it is delivered into the bosh, for of bodies contained in a fluid in motiom the *least dense* acquire the greatest *rapidity* of movement.

With respect to the removal of the washed coal from its compartment, this is effected by means of a worm, which conveys the coal to the hopper of an elevator. This elevator works at

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the side of the bosh, at the outside, and conveys the coal to a shoot, by which it is delivered into a waggon.

In a similar manner the shale and other impurities are removed from their compartment, and elevated by an elevator working on the other side of the bosh, which conveys them to a shoot for deposit in a shale waggon.

There are only two discharges from the machine—one for washed coal, and the other for the impurities—shale, pyrites, &c.

Perforated buckets are used in elevating the washed coal, to admit of the water draining out, which is returned to the bosh, and used over and over again; similar buckets are used for removing the impurities, and the water is returned to the bosh in like manner. It is only necessary to replenish such water as is lost by evaporation and carried away in the coal. After the bosh is once filled, a pipe, $\frac{3}{4}$-inch bore, with a head of 3 feet, will supply a machine capable of washing 20 tons per hour. It may here be observed that in cases where the same water is not used over again, as much as $7\frac{1}{2}$ to 10 per cent. of coal is lost by being carried off with the water.

No settling *ponds* are required with this machine; it is "self-contained," and the settling chamber and method of drainage form an important feature in the design.

The labour of a man and boy is sufficient to work a machine capable of washing 200 tons of coal in 10 hours.

It is calculated that about two pence per ton will cover wear and tear, steam power, and wages in washing.

Fig. 3 represents the outline of one of the boshes of a German (Westphalian type) coal-washing machine designed for use in conjunction with settling ponds.

A machine for crushing coal must be considered as a piece of machinery quite separate from any washing machine, forming in itself a distinct item for consideration. It may consist of a pair of serrated rolls, one of Carr's Disintegrators, or other suitable apparatus.

The machinery for screening the slack also forms in itself a distinct item.

The object of screening is to separate the slack into divisions according to the size of the pieces or particles, so that the slack washed in any one particular bosh, shall be as nearly as practicable uniform in the size of its particles. The purpose of this is to reduce to a minimum any risk of waste of coal, for when the slack is not screened, particles of coal to some slight extent are separated along with the shale, &c. Although the latter are of higher specific gravity than the coal and consequently form a layer on the surface of the grid with the coal above

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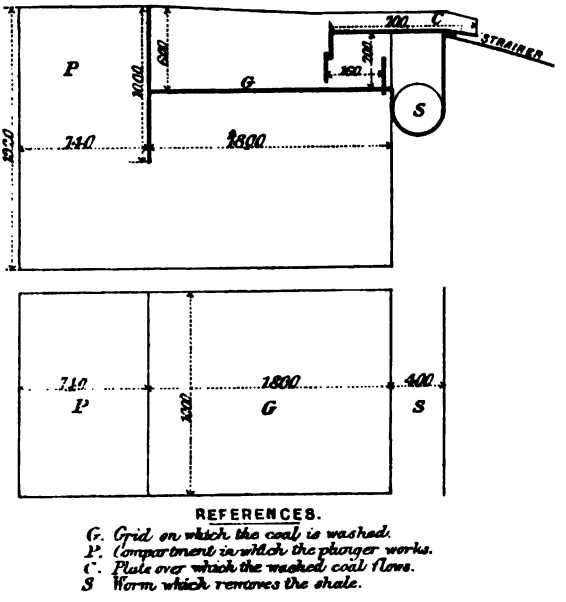
them, yet in consequence of the interstices between those substances, fine particles of coal drop in between them, and are removed therewith. Screening the slack therefore has an

FIG. 3.



REFERENCES.

G. Grid on which the coal is washed.
P. Compartment in which the plunger works.
C. Plate over which the washed coal flows.
S Worm which removes the shale.

important bearing upon coal washing in the prevention of waste of coal.

The holes in the screen should be *perforations* rather than formed by bars or grids, as in the case of a round or square hole there is greater uniformity in the size of the screenings, and the pieces are less liable to become "wedged."

Figs. 4, 5, and 6 represent a type of "Beehive" oven. There is to each oven but one flue, which is at the top. There is an air passage to each oven which conducts air to the back end. The object of this passage is to supply air to effect the combustion of the gas. There is a damper in the chimney, the purpose of which is to regulate the oven, so that the quantity of air admitted shall be sufficient, but not in excess of what is sufficient for the object named.

The ovens are built back to back, and as the coke is watered in the ovens, they are built of considerable strength and of very

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refractory materials, so as to withstand, as far as practicable, the destructive action of the steam.

Fig. 4.

FRONT VIEW

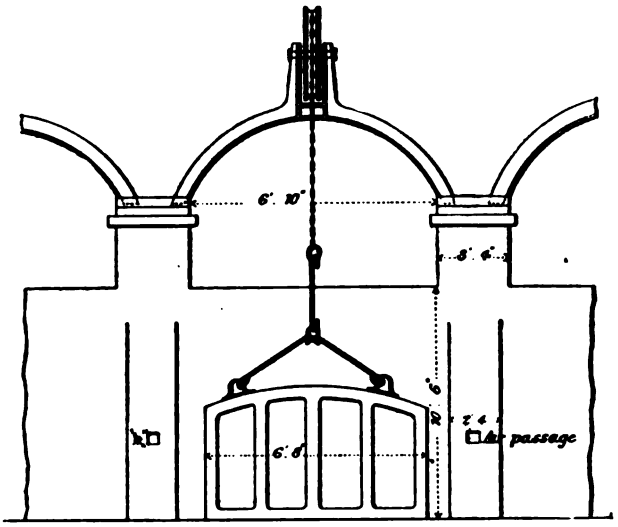
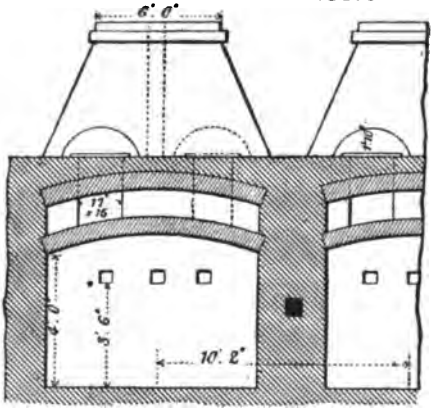


Fig. 5.

SECTION SHEWING AIR HOLES.



In this class of oven the heat is produced above the coal; the coking commences at the top, and proceeds gradually down-

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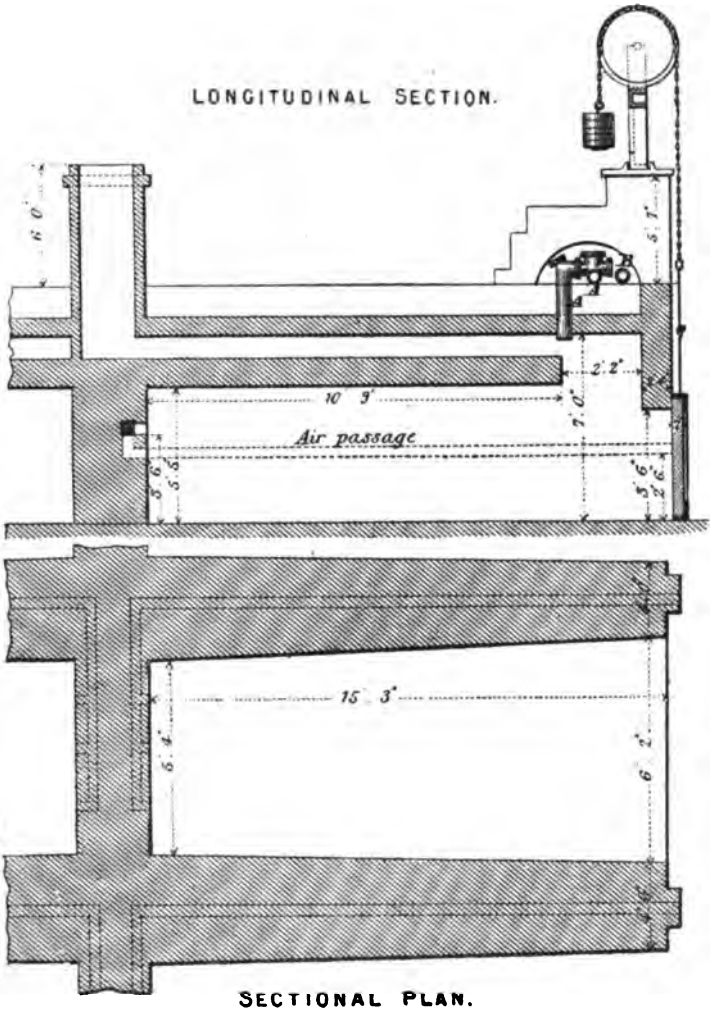
wards. This mode of coking does not, of course, produce the greatest yield of coke, a portion of the fixed carbon being consumed in the process.

FIG. 6.



The ovens, however, produce coke of good quality, and the yield is estimated at about 68 per cent. They produce 6 tons

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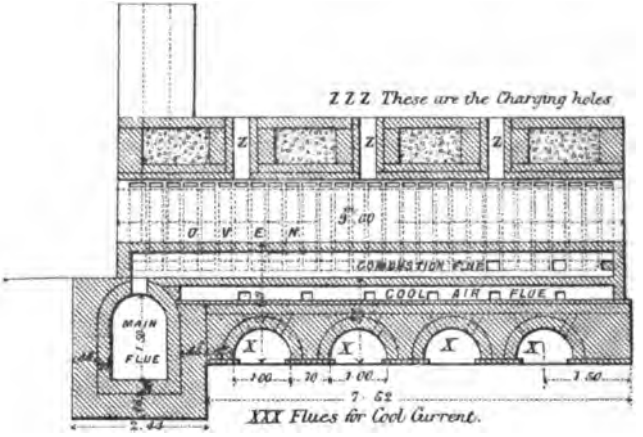
of coke per week, in three charges, at a cost in coking of about 1*s.* 8*d.* per ton for labour.

There is an arrangement for carrying off the spare volatile products, condensing, and collecting the tar and ammoniacal liquors.

Figs. 7, 8, 9, 10, and 11 represent some Belgian ovens (Coppée system). In these ovens the highest temperature is produced, and the ovens are so constructed that the gas shall work off

FIG. 7.



from all parts of the charge at once. The ovens are built upon five longitudinal flues, four are for the passage of cold air under the ovens and the other one is for carrying away the waste gas from the ovens. Transverse to these flues the ovens are built.

The ovens shown on the drawings are, in round numbers, 29 feet 6 inches long, 18 feet wide, and 3 feet 8 inches high. The gas is carried off on one side of each oven, at the top, and thence down a number of small vertical flues in the side. There is a damper arrangement connected with the vertical flues of each oven, to admit air, to effect the combustion of the gas in the flues. From the vertical flues the gas is discharged, either directly into a flue immediately under the oven which gives off the gas, or into the flue under a neighbouring oven. The ovens are worked alternately; whilst one oven is being charged, both of its two neighbouring ovens are giving off the gas at the maximum temperature; and the flues are so arranged that the gases from the newly charged oven shall mingle with those of a neighbouring oven. For instance,

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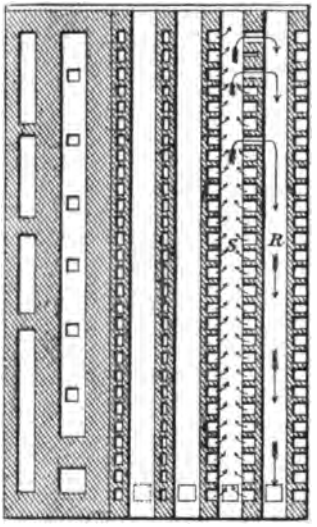
suppose oven R (Fig. 9) is giving off its gas at the maximum temperature, and that its neighbouring oven S has just been charged. The gas from S is carried down into the flue directly under it, and into this same flue the gas from R is also dis-

Fig. 8.



charged. These several gases mingle together in this flue, producing intense heat, and pass afterwards into and through the flue under R, and are discharged from it into the main flue, whence they pass under the boiler or into the chimney.

Referring to the longitudinal cold air flues, there is a partition wall in the middle of them dividing them transversely. The ends of these flues at both ends of the range of ovens are open to the atmosphere. Immediately over these longitudinal flues there are other air flues, which are built transversely to the former, viz., one under the combustion flue of each oven. The two middle transverse flues, viz., one on each side of the partition wall alluded to, communicate with the longitudinal flues by means of openings in the crowns of the latter. These two transverse flues are not connected with each other by any opening, but all the remaining transverse flues communicate with each other by holes in the sides.

The air enters the longitudinal flues at each end of the range of ovens and passes along these flues to the middle. It then enters the middle transverse air flues, and passes through the

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other transverse flues, and is ultimately discharged at the ends of the ovens, into chimneys. The way in which this circula-

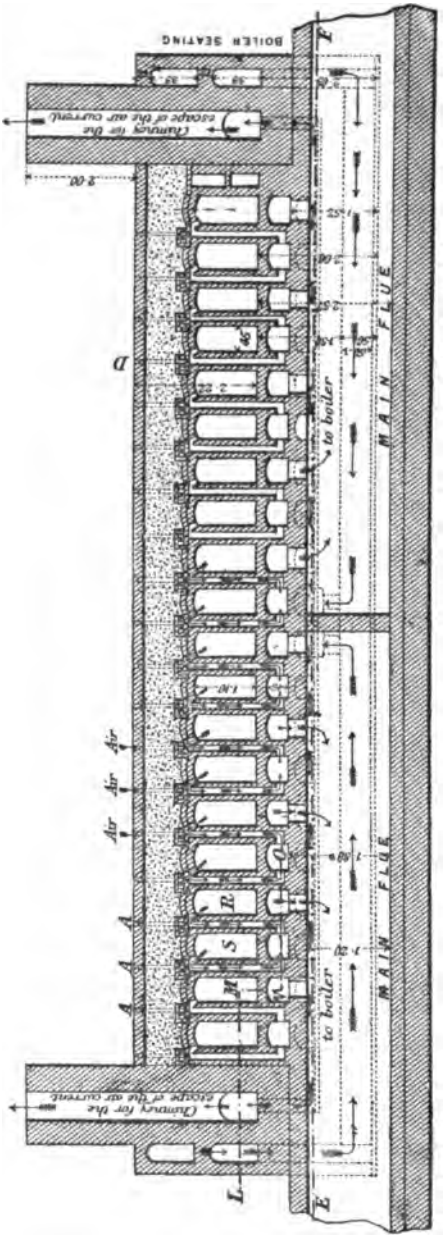

FIG. 9.

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tion is accomplished, likewise the way in which the hot gases circulate, is shown by arrows, see Figs. 8 and 9.

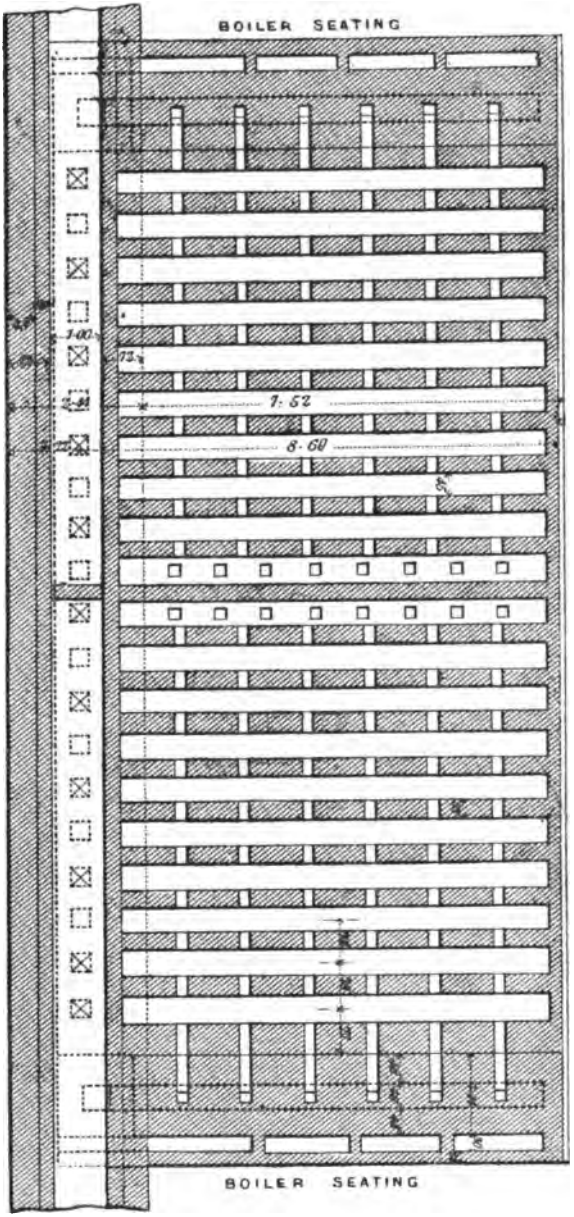

FIG. 10.

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One set of arrows represent the cold air circulation, viz., from the ends of the range to the middle and back again to the ends, and the other arrows the circulation of the gases.

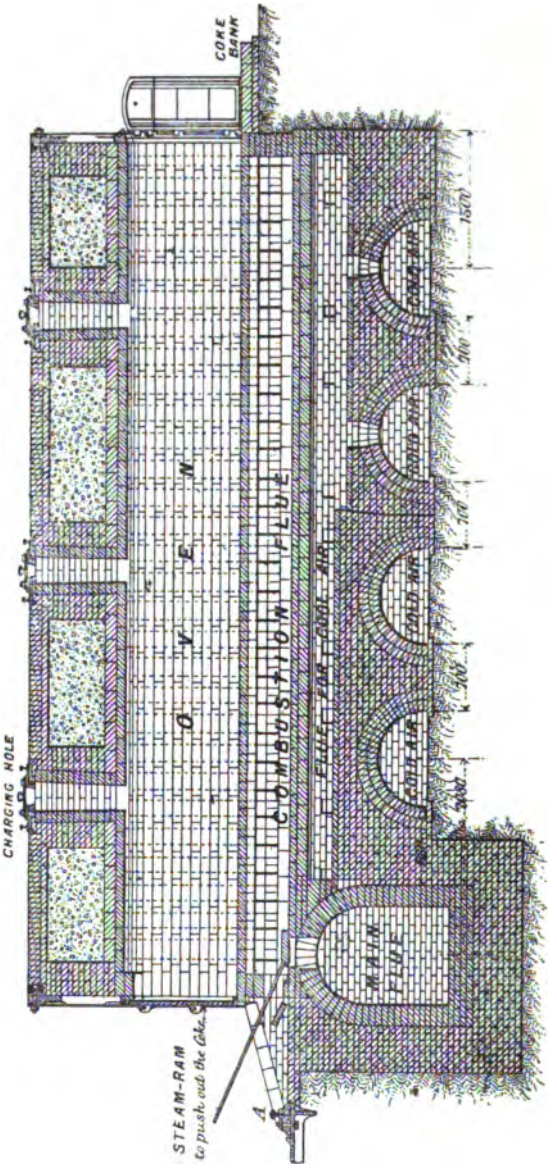

FIG. 11.

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There is but little variation in the temperature of the ovens. The green coal is attacked on all sides at once, and the whole of the contents of the oven coked with scarcely any expenditure of fixed carbon. The ovens are charged from the top. The coal is delivered in waggons which open at the bottom, and discharge their contents direct through the charging holes at the tops of the ovens.

The coke is pushed out by means of a steam ram. The time required to empty and refill an oven is about 8 minutes.

One special feature in these ovens is the means afforded for utilising the heat of the waste gases for the production of steam. Heat may be obtained from these ovens to the extent of 2 to 4 horse-power per oven, depending upon the kind of coal which is coked, and the design of boiler used. Two tons of coke are made in 24 hours at a cost in labour of about 1s., and the yield is about 76 per cent. with coal which yields 68 per cent. in the ovens first described.

The writer exhibited a sample of washed coal; also a sample of unwashed coal; also a sample of rubbish separated from unwashed coal, similar to the sample. The sample of washed coal had also been separated from unwashed coal similar to the sample.

DISCUSSION.

Mr. HORSLEY said that the author had referred to the use of coke in blast furnaces. It appeared to him that if smelters had to wash and coke all the coal used in blast furnaces, it would be an endless job. He supposed that the author meant the cupola used in the remelting of iron. He should think that there were now very few furnaces in Derbyshire where iron was smelted with coke.

Mr. NURSEY said that coke was largely used.

Mr. HORSLEY said that it was so in some counties, but not in his county. In the Midland Counties they used hard coal. He should think that if a district could get good hard coal, with very little sulphur or pyrites in it, he did not see any good in washing the coal; but he could quite understand coal being washed in cases where it was of an inferior quality. Nearly the whole of the coke used in Derbyshire for remelting iron came from the Durham district. The Derbyshire coal generally would not make coke, but some few would make strong coke enough for remelting iron. Therefore, with regard to coking, a great deal depended on the nature of the coal. Some years ago the coke

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ovens in London used what they called Tanfield coal for coking. That coal was never washed, but it made remarkably good coke. The machine for washing coal had not come under his notice. He was not sure in all cases whether the coal used for remelting iron would pay for washing. If the gas which came from the coke ovens which had been described could be collected, the invention would be a very valuable one.

Mr. PERRY F. NURSEY said it might help to direct the discussion into its proper channel, if he drew attention to the fact that the paper was on The Utilisation of Coal Slack in the Manufacture of Coke for Smelting. Mr. Horsley had mentioned that in his county ironmasters used very little coke for smelting, working principally with coal. In the north of England, however, an enormous amount of coke was used for smelting; and he had visited several collieries where they had coal washing and coking apparatus at work, and manufactured from the slack excellent coke for carrying the burden in blast furnaces. In all collieries there was an enormous quantity of slack or waste produced in working, which, under ordinary circumstances, would be thrown aside, because it generally contained a large amount of impurities, and the object of washing it was to get rid of those impurities. The general principal in coal washing was to carry the coal down an incline with a stream of water, and to allow the impurities to deposit themselves by their relative specific gravities at different distances from the point at which the stream of coal entered the water, the pure coal being carried over into catch-pits at the end of the run. He had seen that system worked very successfully in many instances, and on a very large scale at some collieries. The paper intended to bring before the meeting the best system for utilising what would otherwise be a waste substance. Of late years coal-dust washing and the manufacture of coke from the washed dust had proved very successful. It was extensively practised at several collieries in the Barnsley districts. Amongst others at which the process was carried out were the Silkstone and Dodworth, the Wharncliffe Silkstone, and the Thorncliffe collieries. About three years ago he visited several of those establishments, of which the Silkstone and Dodworth Works, situated at Dodworth, near Barnsley, were the most complete and extensive. Being typical of the rest, he would describe the arrangements there. The coke was made from the dust and refuse of the workings. As the corves were raised from the pit—and they were raised in double lifts at the rate of four corves per minute from each of three shafts—the coal was tipped out on to a screen, the best household coal passing at once into the railway waggons. The

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largest "nuts," as they were termed, together with the "pea-nuts" and "smudge" or dust, pass through screen No. 1 on to screen No. 2; the large nuts being delivered into waggons on the other side for use under steam boilers. The pea-nuts and smudge fell through screen No. 2 into a hopper, which opened into a covered trough, in which was an Archimedean screw 60 feet long. There were four of those screening apparatus delivering into the screw-trough. The small coal was delivered at the far end of the screw into a pan, in which dipped a Jacob's ladder, which was a series of buckets on an endless revolving band. These buckets carried up the small coal to a revolving screen or riddle, from which the pea-nuts passed to a receiver, to be run out when full into waggons, for use for steam purposes and gas making. The smudge was conveyed from the revolving riddle to two inclined troughs, which united into one at a point some 200 feet away. A constant and copious stream of water flowed through the troughs, carrying the coal dust with it. Mixed with the coal dust was a large percentage of metallic and other impurities, which must not be allowed to get into the coking ovens, or the coke would be spoilt. The flow of water, and the inclination of the troughs were, however, so adjusted that the impurities of their own superior gravity settle in the trough, the lighter particles of pure coal being carried onward to a series of draining tanks, which commenced at the 200 feet distance. The draining tanks were formed of finely-perforated metal plates, and in them the coal dust was deposited, the water draining off into a conduit beneath. The tanks were so arranged that as each became full the stream of coal and water could be shut off and allowed to pass in turn to the others. The coal dust thus collected was removed from the tanks into corves, and taken to the coking ovens. The water after passing all the draining tanks, still held a considerable quantity of coal in suspension, and was, therefore, led away to settling ponds, whither also that which had drained from the tanks was conducted. At the head of the settling ponds were two compartments, 60 feet long by 15 feet wide, and 3 feet deep. They were used alternately, and as one became filled with coal dust, the water was turned into the other, and the full one was emptied, the deposit being conveyed to the coking ovens. The water from the compartments flowed into two others in succession, each of which was 60 feet long, 30 feet wide, and 4 feet and 5 feet deep respectively. There the last particles of coal settled, and were removed as the compartments became full, and were taken to the coking ovens. The water, now comparatively clean, flowed away, still by gravitation, back near to the revolving riddle, and

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was there pumped up again to the troughs, after having completed a circuit of over 1000 feet. The pumps employed for that purpose were one of Tangye's and one of Hayward Tyler's steam pumps.

There were two blocks of coking ovens at Dodworth, one containing fifty and the other thirty ovens, which were placed in double rows, back to back. The ovens were charged with the coal dust at the top, and the waste gases were taken off by a flue running centrally between the rows. At the end of the block of thirty ovens, which were of the Staffordshire arched type, was a row of seven Lancashire double-flued boilers, each 30 feet long, 7 feet diameter, and with 2 feet 9 inch flues. Two boilers in the series were heated by the waste gases from the coking ovens, and a third was being fitted for the same purpose at the time of his (Mr. Nursey's) visit. If the gases were not required for the boilers, they could be shut off and conducted to a tall chimney shaft. The boilers supplied steam to the winding and other engines. At the end of the block of fifty coking ovens, which were of the bee-hive pattern, four new boilers were being laid down, and were all to be heated by the waste gases from the ovens. Those boilers were egg-ended, 30 feet long, and 6 feet diameter, and fired underneath. There were, besides, three other boilers of the same type, supplying steam to the engines. All the boilers were connected into one main series.

In the Durham district he (Mr. Nursey) had visited several collieries where they had washing and coking apparatus, the coke being principally used for the smelting of iron as well as for locomotives.

When in Alsace-Lorraine, in 1878, he had visited some extensive collieries and iron works belonging to the De Wendel's, who owned altogether in that district about 80,000 acres of land, and employed 12,000 work people. They had four or five establishments for smelting and manufacturing pig and merchant iron as well as engines and machinery of all kinds. They also owned several collieries, besides a large coking establishment at Hirschbach, near Saarbrucken, where the coal from their own collieries near Hirschbach was washed and made into coke by means of Appolt ovens and Coppée ovens. In the Appolt ovens the coke was placed in vertical chambers surrounded by an annular space. The coal was fed at the top, and the gases escaped at the bottom into the annular space, and heated the sides of the oven. The coke was drawn from the bottom. The Coppée ovens were the ordinary type, in which there was a flue at the bottom through which the products of combustion were led, so that the bottom of the oven was heated and the coal was

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burnt at top and bottom as well. A considerable economy resulted in the production of coke on those two systems, the total yield there being about 600 tons per day at the time of his visit.

He observed that it might be interesting to the meeting if, before sitting down, he referred to an incident of war in connection with Messrs. de Wendel's rolling mills at Stiring-Wendel, which are situated about 36 miles from Metz, and which he had also visited. Those works possessed a very special interest, from the circumstance that they were the site of the second great battle fought during the Franco-Prussian War, the first having been that of Wissembourg. The second battle was known as that of Forbach, having taken its name from the town of that name about a mile and a quarter nearer to Metz; but it was really fought at Stiring-Wendel. The works comprised large rolling mills, fitting shops, and offices, to which were formerly attached blast furnaces, but which the battle laid in ruins. The works lie at the base of the heights of Spichern, which formed the frontier of Rhenish Prussia. In front of the works ran the railway, and on the other side of that was a large house and grounds, occupied by the manager of the works, a row of houses built for the workpeople forming a continuation of the same. To the rear of the works was the town of Stiring-Wendel, with its stone-built church and schools, all of which were erected by the De Wendels. The attack on the 6th August, 1870, was commenced by the Prussians, who crept down from the heights behind the manager's house, of which, with the row of cottages, they quickly possessed themselves, and opened fire upon the French troops. Up to within a few hours of the battle the men were working at the blast furnaces, the puddling furnaces, and in the rolling mills. The French troops drove the Prussians from the manager's house; but it was speedily retaken, and the French driven back into the works, of which the Prussians soon possessed themselves; but were in turn driven out, only however to regain possession. It was in those works that the battle was ended, more then a thousand men having fallen under the roof of the main building, which is open on all sides. The blast furnaces were destroyed by fire, and damage to the extent of 1,500,000 fr. was done to the factory generally. The manager's house was riddled with bullets, the holes still remaining, while the houses and buildings in the town retain marks of the strife. The reason why the blast furnaces were not rebuilt was because the ores formerly smelted there were afterwards taken to some of Messrs. De Wendel's other blast furnaces, and the pig iron brought thence to Stiring for working, with a saving in favour of the arrangement.

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Mr. GANDON said that he should like to know what proportion of slack was washed out of, say, a ton of coal. It appeared to him that the refuse from the coal must be very large indeed. As a gas-engineer, he knew the trouble which they had to encounter with pyrites and other things which existed in ordinary Newcastle coal, or such coal as was got for gas-making; but he certainly had never tried washing the coal, and, of course, gas-makers would be unable to wash their coal because it existed in large pieces. He did not, however, think that in those coals there were nearly as much pyrites as in the coal mentioned in the paper. He should imagine that there must be a large quantity of coal washed away by the machine; for although it was a very ingenious plan to take advantage of the different specific gravities of the coal and of the impurities, he thought that there must be some coal carried away with the impurities. He supposed that in those places where the slack was used as described in the paper, it would be almost a refuse material unless it could be utilised in that manner. He presumed that the coal must be what was called a caking coal in order to be capable of turning into coke. In many of the coals of the Midland counties, as Derbyshire, and also in the Welsh coals, there was no caking property; and therefore such coals, if reduced to the small pieces which formed slack, could not be turned into coke.

The PRESIDENT asked whether the slack of Derbyshire coal was used at all.

Mr. GANDON said that he did not know, but he knew that in Wales there was a great deal of difficulty in getting rid of the slack of coal which would not cake. Perhaps Mr. Nursey could enlighten them on the question as to the proportion of slack.

Mr. NURSEY said he regretted he could not do so. His observations had been made simply as a visitor to the works, and not as a practical coke-maker, and were therefore more or less general, except as to the Dodworth works.

Mr. C. J. ALFORD said that there was one remark in the paper which he could corroborate, and that was that the exposure of the coke to the weather improved its quality as a household fuel. It was his lot, at present, in connection with the Gas Light and Coke Company, to deal with perhaps the largest amount of gas coke that any one had to deal with. In the winter of 1878–79 about 120,000 chaldrons of coke accumulated at Beckton. The greater part of it lay in a heap exposed to the weather until barely a month ago, when the last of it was cleared away. During the last few months of that period,

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he had seen and heard that the coke which had been taken from the heap had borne a very much higher character for household purposes than the fresh coke from the retorts. Some 20 per cent. of it had certainly been lost in breeze, but much of the sulphur had disappeared, and the coke that remained was approved of more than the fresh coke on that account, the sulphurous fumes given off by coke in burning being the greatest drawback to its use as a domestic fuel.

Mr. HORSLEY asked Mr. Nursey whether he could state the cost, from beginning to end, of machinery, plant, and everything required in the process of washing coal as described in the paper.

Mr. NURSEY replied in the negative.

Mr. HORSLEY said that he should conclude that if coal could be obtained at 5*s.* a ton at the pit's mouth, as it was in Yorkshire, it would cost almost as much to wash the coal. He should say that the coal must be very bad if it was found necessary to wash it all through. From what he could gather, it cost about 2*s.* 6*d.* a ton to get the coal through the washing machines and coke ovens and then there was waste besides; and therefore he should say that the process would only pay when the best hard coals cost 10*s.* per ton or upwards at the pit's mouth. As Mr. Gandon had said, the Durham coal would cake very well, and it answered for smelting purposes; but as to Derbyshire coals, very few of them would cake at all. Some years ago, he saw about 300 coke ovens put up for the purpose of coking coal for locomotive engines. They were put up before the coal was properly tried, and, as it was found not suitable, the ovens had to be pulled down again.

Mr. NURSEY said he could not say what was the cost of the process. It would vary according to the extent of the output of the coal and the character of the slack. The process was largely carried on in the north, and that being the case, he thought that they were bound to take it that it was one which paid; for they were very keen folks in the north, and as recently as last autumn he found that in one district the application of coal-washing apparatus was being considerably extended. That would hardly be the case if there was not some profit attached to the process.

Mr. GANDON, referring to the question of cost which had been raised by Mr. Horsley, said that if his memory served him rightly, the paper stated that the cost of burning would be about 1*s.* a ton. He should imagine that the process could not be a very expensive one, if about 20 tons per hour could be washed, and the machine could be served by a man and a boy. Of course, the cost of the plant and machinery must be added,

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The PRESIDENT, in closing the meeting, said that the paper was, no doubt, somewhat difficult to follow, and there were so many points of detail that it was very difficult to raise a discussion upon them. A few questions, however, had been asked, most of which, he believed, had been answered mutually, the author being unfortunately absent. As to the question of whether a coke or a coal was suitable for a particular purpose, that must necessarily be a question of the amount of sulphur and pyrites which the fuel contained. Where a coal was found to abound in sulphur, and it was capable of caking, the coal would require changing into coke and might be washed with advantage in these coal-washing machines. As to the coke ovens, very little had been said in the discussion, and the meeting must take the author's figures, as they had not been disputed. When members came to read the paper at their leisure, they would consider whether or not they agreed with those figures. They were indebted to the author for having brought the subject before the Society.

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April 5, 1880.

JOSEPH BERNAYS, PRESIDENT, IN THE CHAIR.

DISTILLING AND HOISTING MACHINERY FOR SEA-GOING VESSELS.

By HAMILTON WELDON PENDRED.

The branch of engineering dealt with in this paper, though less important than some others, is still useful to a maritime nation, and as it possesses some features peculiar to itself, the author thinks a short description of its appliances may prove interesting to the Society. At first sight the title of this paper might be taken to denote two different subjects; but such is not really the case, because, as will presently be shown, though the class of machinery with which this paper deals is usually divided into independent arrangements, still the hoisting machinery is often combined with the distilling apparatus. The author regrets that he has been unable to obtain diagrams or particulars from more than two firms besides the one with whom he himself, several years ago, acquired his own knowledge of the subject.

Sea water distillers either resemble those used for other purposes, consisting of a worm in a tank, or else they are ordinary multitubular surface condensers, the stream passing through the tubes, and the condensing water circulating through a tank containing them. Fig. 1 shows a Graveley's distiller, capable of yielding 80 to 100 gallons per day of ten hours, and suited for a ship 1000 to 1500 tons. This diagram illustrates the distiller combined with the cooking hearth, which has two 14-inch ovens, a hot plate, and at one end a copper or iron boiler unequally divided by a partition, the largest part for soup, &c., the other making tea. The distiller here consists of a plain square boiler, sometimes with one cross tube in it dropped into the hearth, being supported by two angle-irons riveted to its sides. The front of the hearth is dipped down over the fire-door, as shown, to admit of a water gauge. A grate and ash-pit are in the hearth beneath the boiler, and the flue is taken off either inside past the oven, or outside the back to the uptake. Hence the process of cooking and distilling may go on either together

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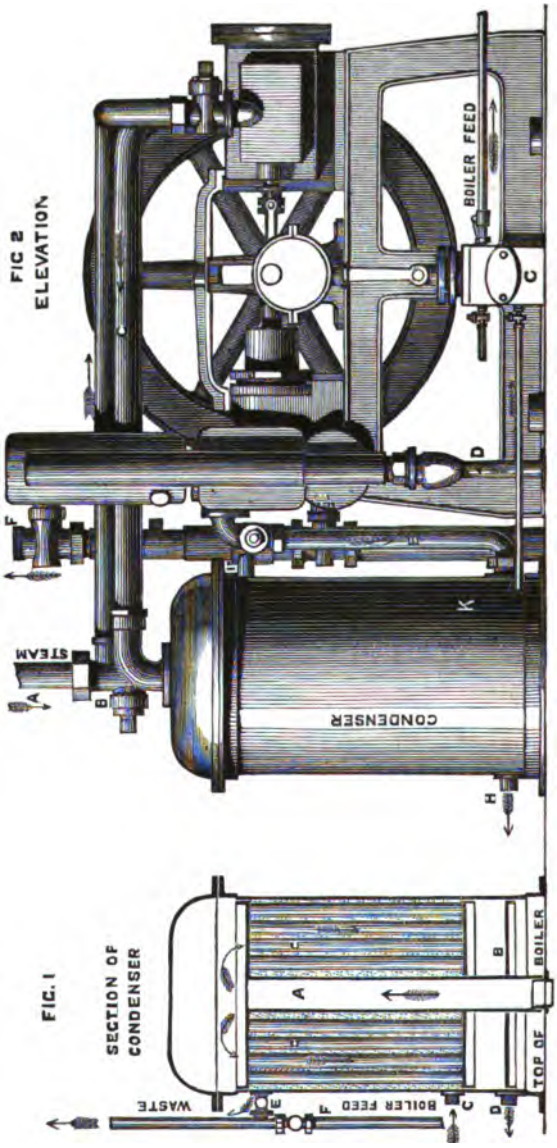
or separately. In small hearths but one distiller is fitted on the



boiler, but on large hearths a pair are provided. Distillers for such hearths consist of a cylinder, either of copper or galvanised

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BILGES OR SEA

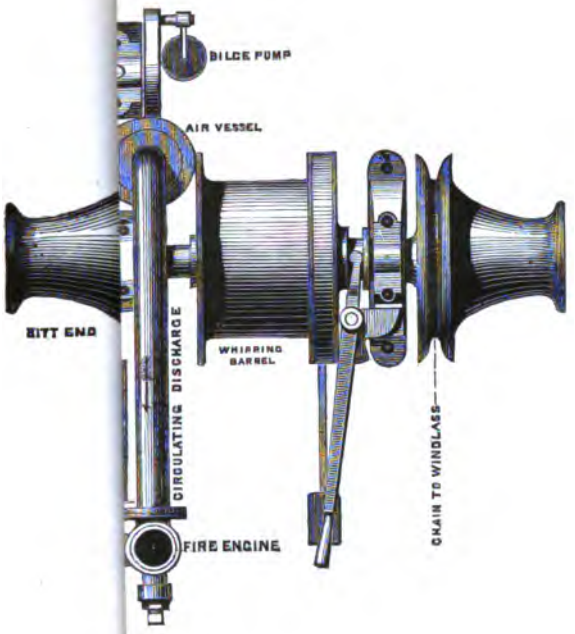
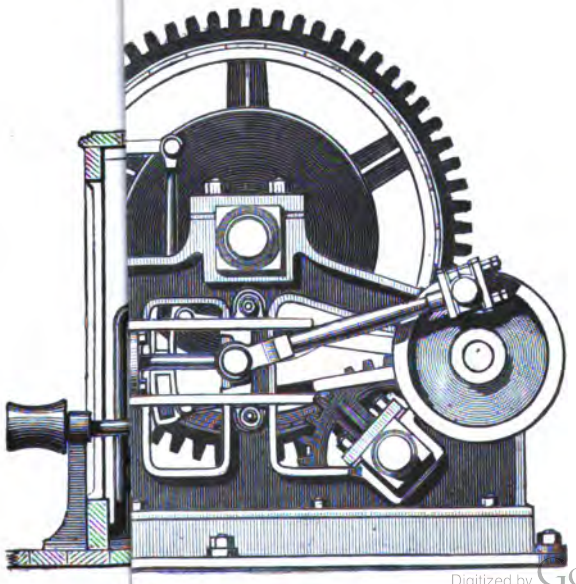


FIG. 7



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iron, 10 inches to 12 inches in diameter and 18 inches or 20 inches high. It has a tube-plate carefully soldered or brazed a little way from each end. Up the centre—Fig. 1—is a tube A of three or more inches in diameter, whose lower end projects some inches below the cylinder, passing through a plate which forms the bottom of the cylinder, situated some 2 inches from the tube plate. A number of ¾-inch tubes C C are fixed between the tube plates, into which they are soldered or brazed; the condenser is covered with a dome top. A supply of cold water from a sea-cock, where the hearth is below the water-line, and where above the water-line pumped for the purpose, is circulated through the cylinder outside the tubes. The steam rises from the boiler through the central tube above the upper tube plate, and then returning through the small tubes is condensed. The fresh water thus produced is received in the bottom chamber B, and is drawn off to the store tanks by gravitation or pumping. The same stand-pipe conveys away the circulating water and also supplies the boiler, cocks E F being fitted to regulate both. These distillers are sometimes made separate from the hearths.

Fig. 2 illustrates a larger apparatus, consisting of a horizontal donkey engine with a condenser at its end. The cylinder is 4 inches in diameter with a stroke of 5 inches, the plunger 3 inches in diameter. This will distil from 500 to 2000 gallons per ten hours. The condenser K is 2 feet 10 inches high over the dome, with an outside diameter of 1 foot 3 inches. It contains sometimes simply a worm, but more often a cluster of ¾-inch tubes, as in the condenser last described. Steam is supplied by a return tube-boiler, either flat-sided or cylindrical; the flat-sided boiler is usually 4 feet in length, 4 feet 6 inches in height, and 2 feet 9 inches in width, with one fire tube, twelve or fourteen tubes 2½ inches diameter, and one steam box; the cylindrical boiler is 3 feet 9 inches by 5 feet, with one fire tube 1 foot 9 inches in diameter, and eighteen or twenty return tubes 2½ inches in diameter; it has two steam boxes 1 foot 9 inches in diameter by 18 inches high. A glass water gauge is sometimes fitted on the lower part of one of the steam boxes; the steam does not enter it direct but through a tube from its fellow, as some provision against priming, for, if any takes place, it will be caught in the second steam box—and its presence detected by the gauge—from which it can be blown out. The steam from the boiler passes in at A and flows to the valve chest, which is provided with a regulator of its own; at B on the condenser is a cock through which steam can be admitted direct to the condenser. The exhaust steam from the engine passes through

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the pipe C to the condenser, furnishing its quota of distilled water. The engine works the circulating pump, and the suction is shown at D, with a small air vessel. The delivery from pump to condenser is at E at the bottom of the condenser; the screw union for the out delivery is at F; the water from this union is brought into service in case of fire, for washing decks, or any other requirement. The feed pump is at G, and the fresh water runs at H.

In a larger distilling apparatus, the engine is mounted on a tank containing the condensing tubes, which, with their plates, are secured to the door, and can be withdrawn when requisite. The leading dimensions of this engine are: cylinder, 7 inches diameter by 10 inches stroke; pump plunger, 4 inches diameter by 10 inches stroke. The condenser consists of eighty tubes 3 feet 10 inches in length by 1 inch outside diameter between plates, giving a total external surface in round numbers of 1 foot per tube. The external size of the condenser casing is: length, 4 feet 9 inches; width, 1 foot 11 inches; and height, 1 foot 5½ inches. The steam is caused to traverse the tubes in sets, moving twice forward and once back by deflectors in the tube plate covers. On the end of the crank shaft is mounted a pinion 7⅜ inches diameter, fifteen teeth 1$\frac{9}{16}$ inch pitch, gearing into a spur wheel of sixty-eight teeth 3½ inches wide, and a pitch diameter of 2 feet 9⅜ inches; this is mounted on a shaft, 2$\frac{5}{8}$ inches diameter, running across the ship's deck-house, so as to have the bitt ends clear of its sides. On this shaft is a winding barrel, of 3 feet in extreme length, and 2 feet 7 inches on the barrel, which is 6 inches to 7 inches in diameter. A brake and clutch gear is provided; bitt ends for sundry pulling and hauling are fitted at the ends of the shaft, the latter being supported by A frames bolted to the deck or to the coamings of the deck-house. On one of the bitt ends is a chain wheel, and a pitch chain is led from this to the windlass to weigh the anchor, and it is also used to work the deck pumps when needed. A clutch is fitted to the spur wheel, so that if the engine is only making fresh water the main shaft spur is put out of gear with the shaft. The boiler to work this engine may be 3 feet 9 inches in diameter, 5 feet in length, with twenty tubes of 2¼ inches inside diameter, a fire tube of 1 foot 7½ inches diameter, and a grate 2½ feet in length by about 4 square feet area. Assuming this to burn 20 lb. of coal per foot per hour, and to evaporate 9 lb. of water per pound of coal, it would give, neglecting waste, seventy-two gallons of fresh water per hour. The door of the condenser is secured by studs and nuts, a guide for the piston-rod is provided beneath it, and a gun-metal "eye lug" is bolted to the crosshead and works on

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the guide. The pressure of steam is usually about 45 lb. The water, of course, is filtered subsequently, but the Gravely system did not include special appliances for aërating the fresh water, the patentee arguing that, as air was pumped into the boiler with the feed, it must pass off with the steam, and that the subsequent filtering, storing, and pumping into tanks also aërated it.

Fig. 3 illustrates another and still larger engine by Messrs. Gravely, fitted on board the Australian liner *Hydaspes*. Generally it is similar to the engine last described, save that it has two cylinders, a link motion, and has pumps vertically arranged at end of condenser, and the several parts are marked on the diagram.

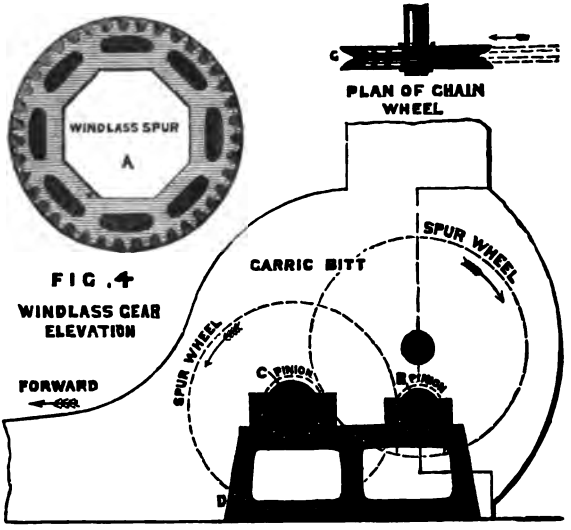

FIG. 4
WINDLASS GEAR ELEVATION

It has been said a chain was led from the chain wheel to the windlass. Fig. 4 shows a windlass such as ships of 1500 and 2000 tons have; a double set of powerful spur gear is fitted to it, the windlass spur being a sort of ring with an octagonal centre, which embraces the end of the port side of the windlass. Iron bearings bolted to the carrick bitts carry the inner ends of the first and second motion shafts, the outer ends being borne by a frame secured to the deck. The windlass spur is 3 feet in diameter, the pinion 9½ inches in diameter, the pitch of teeth $1\frac{5}{16}$ inch, and pinion 7 inches in diameter. A clutch gear places the windlass under independent control; G is the chain wheel taking the power.

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An apparatus for use on land is made by the same firm, and such an apparatus, if provided with a boiler capable of burning any vegetable substance available, would be a most valuable machine in some wild and new countries. It is well known that there are wide tracts in the Australian Bush where the water is so brackish that it is very unwholesome, either for animals or human beings. There such a machine would be invaluable. It consists simply of a vertical boiler or condenser and enclosed worm, a donkey circulating pump and a boiler feed pump to supply the boiler with water. The whole is mounted on a frame and wheels for transport.

Messrs. Robertson, Osborne, and Co. manufacture a horizontal steam winch shown in the accompanying drawings, Fig. 7. The drawings are respectively a side and a front elevation of their horizontal steam winch. They have a couple of 6-inch diameter cylinder 10 inches stroke, the lap of valve being $\frac{1}{8}$ inch and the lead $\frac{1}{16}$-inch, and are regulated by the ordinary link motion. The gearing is wheel and pinion, first power being 5 to 1, with a pitch of $1\frac{1}{8}$-inch, and the second power 2 to 1 with a pitch of $1\frac{1}{2}$-inch, thus representing 10 to 1 when working double-purchase, and are constructed to lift 3 tons single-purchase, the power being changed by jaw clutches and the usual levers. They are provided with powerful friction brake chain barrels 12 inches diameter and 2 feet 10 inches clear of brake wheel, warping ends and chain wheels to windlass and pumps. All shafts journals are bushed with brass and capped, so that they can be lined up and generally overhauled without interfering with the fixtures of the machine, connecting rods top and bottom being coupled with bolts and brasses, valve spindles passing through back of valves and secured with double nuts, the copper pipes with stop valve connecting cylinders being flanged to valve casing and not to door, so that the valves can be examined without breaking pipe joints, the exhaust steam and water formed in cylinders at starting passing into pipe cast in sole plate and then over ship's side by malleable iron pipe and coupling. The total deck space occupied over all is 4 feet 6 inches by 6 feet 9 inches, that is from end of cylinders to outside rim of crank disc and across cylinders. This is a little more than is taken up by the diagonal type, but the great advantage accruing not only to the winch itself but to the ship's decks from the centre of piston strain on crank and centre of barrel left being nearer the sole plate or holding down centre amply compensates for the extra space required, the winch and decks lasting longer and giving more satisfaction to all parties. In discharging cargo, this size of winch is considered equal to fifteen men, and will load or discharge 20 tons per hour of pig iron

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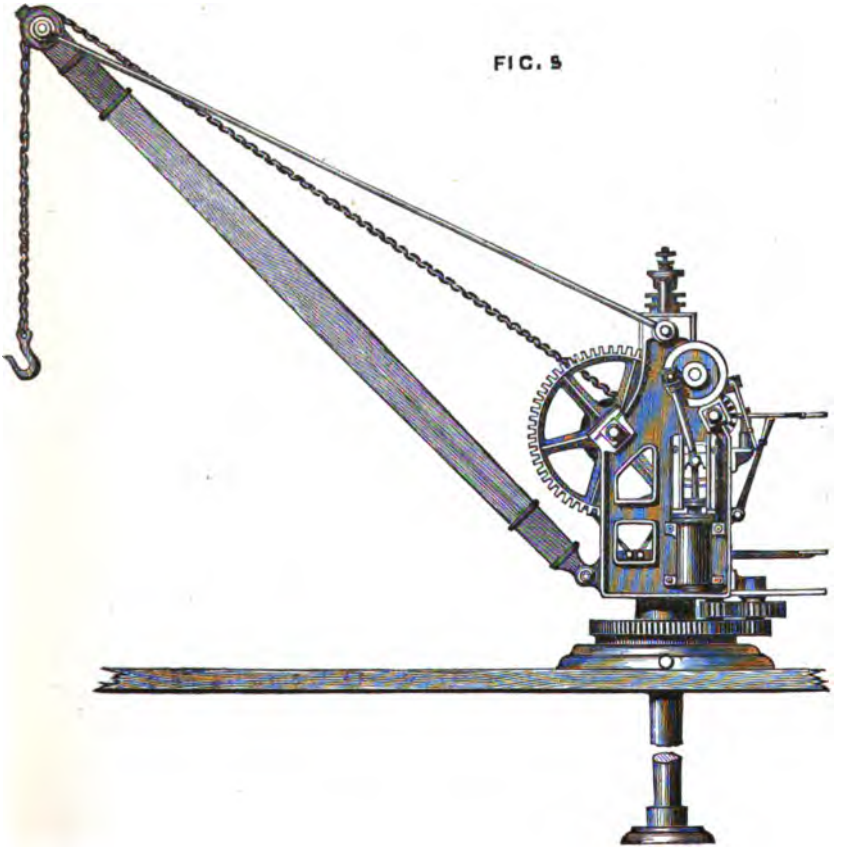
or other slung goods of this class, and bale goods, such as linen, cotton, &c., at the rate of 40 tons per hour, and requires 20 to 25 cwt. of common Scotch coal per 12 hours' constant work with a pressure of 40 lb. to 45 lb. steam, and will take about thirty minutes to lift anchor with, say, 45 fathoms of chain. A ship of 1000 tons can be managed with three hands less, but speed

FIG. 5



being the great object the same number of hands are generally kept. For a 1000 ton ship this size of winch is ample, but for over this tonnage for heaving anchor a 7-inch cylinder winch is preferable.

Fig. 5 is a side elevation of ships' steam deck cranes built by the firm, and these cranes are specially arranged for loading and discharging ships, especially where the cargo has to be loaded or discharged from lighters, a method very generally adopted

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in foreign ports; with a slight modification they are suitable for wharf, railway, and general purposes, in which case they can be made portable or fixed, all being arranged to hoist, lower, or turn round seperately or simultaneously as desired. As per drawing they are fitted with a pair of 6-inch diameter cylinders, the gearing and general details being same as steam winch, the slewing and mitre wheels being of malleable cast iron and centre column or spindle of solid forged iron extending to lower deck, where it is received by a strong step plate, the top part of column being bored out and forming a steam passage to cylinders. They are arranged for same lifts as the winches, 3 tons single-purchase, and are sometimes placed in centre of ship and sometimes to port or starboard. The jib is of red pine with iron sockets.

Fig. 6 is an elevation of Brown's patent fresh water condenser, A being the outside casing or dome inclosing the group of condensing boxes, B B is the worm chamber, C the filter or charcoal chamber, D the inlet aërators, and P and O the outlet aërators. Fig. 7 is a sectional elevation through A B C D and K, the combined group of boxes A B C D E F G, and the two port doors H H and K K, forming the connections and passages from box to box.

In using this apparatus, the steam at 25 lb. to 30 lb., which generally gives the best results, enters at D the inlet aërator, and through a pipe to the series of condensing boxes, as shown by the arrows, where it is completely condensed, and then into cooling worm tinned outside and inside, where it is cooled down, and passing into the filter chamber C percolates down through charcoal on the one side of centre plate M, and up the gravel on the other side, and is run off to ship's tanks through a cock E. A small test cock is provided, so that the man in charge may test the water before it goes to the ship's water tanks. Connection is supplied by steam donkey pump drawing from sea, the discharge pipe being flanged to worm chamber F; the cooling water passing from this chamber enters the dome chamber A, when it circulates among the condenser-boxes as shone by the water line, and is discharged over ship's side or coupled to hose and led to any part of the ship. These distillers are made any size, the general sizes being No 1, to make 12 to 15 gallons per hour; No 2, to make 25 to 30 gallons per hour; No 3, to make 40 to 45 gallons per hour; and No 4, to make 80 to 85 gallons per hour. They are passed by the Board of Trade, the allowance being from six pints to one gallon for each person, according to the climate the ship is to trade in.

A view, with deck-house in section, of this firm's general

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method of fitting the steam winch, boiler, distilling apparatus, donkey, circulating, and feed pumps, in sailing ships was also shown. The steam winch is horizontal geared, with a couple of

FIG. 6.

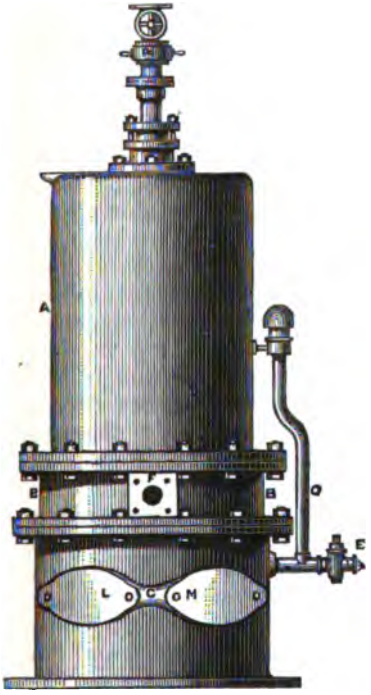
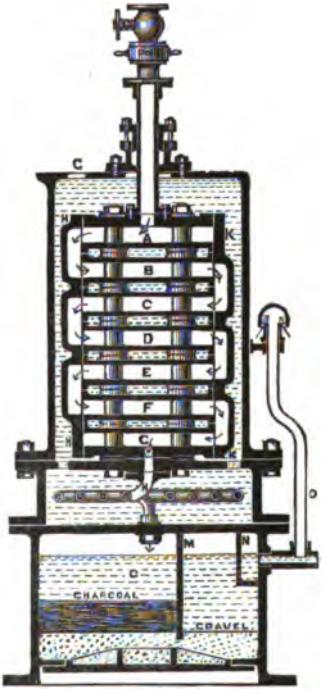
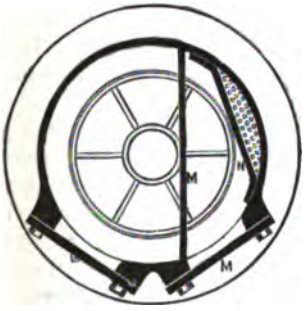


FIG. 7.





6-inch cylinders, and on board ship is set on wooden chocks, and bolted to deck, the space between the chocks beneath the

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winch being filled up with cement. The boiler is 8 feet by 4 feet, with two 14-inch solid welded cross tubes, with the usual doors and all mounting complete, inclusive of Government safety valve, Salter's relief valve, pressure gauge, check valve for feed, steam, scum, and blow-down cocks, as also an improved prime preventer, so that it is impossible for any brine to pass into the distiller along with the steam to be condensed. It is provided with a cast iron sole plate or ash pan bolted to deck and run round with cement, as is also the whole of deck-house floor. The safety valve is arranged to blow off at 45 lb., boiler having been tested to a water pressure of 100 lb. per square inch. The steam pipe is flanged to the blow-down pipe, which again is flanged to the overflow pipe from the distiller, and discharged over ship's side. The distilling apparatus, Brown's patent, as described above, is guaranteed to make from 40 to 45 gallons per hour fresh water from sea water. The combined double-action circulating and single-action feed steam pump is specially adapted and arranged for the purpose, the water barrels, chambers, valves, &c., being of solid brass; the ram in the circulating pump is $2\frac{3}{4}$ inches diameter and 6 inches stroke, and draws from sea and circulates cooling water through distiller; the plunger of feed pump being $1\frac{1}{4}$ inch diameter and same stroke as the other, being driven by a stud fixed to main piston and ram rod. The cooling water is drawn from sea, and this suction pipe is generally led along the deck in a covered gutter to fore peak, where it is connected to ship's side by a sea cock, and is discharged into distiller, and after doing its work overflows over ship's side. A coupling is attached to this pipe outside of deck-house, so that a hose can be connected and the overflow water used for washing decks or assist in case of fire. The feed is taken by the small pump from the circulating water in distiller, partly warm; the steam is supplied to the donkey through a pipe, regulated by a wheel valve, the exhaust passing into funnel. The extension through the deck-house is provided with warping ends carrying standards and couplings and chain wheels to windlass and ship's pumps.

Coming now to the application and working of the foregoing machinery. For loading or discharging cargo at a quay side the fore or main yard of the vessel is braced over the quay at a convenient place, and a block fixed at the yard arm, through which a rope is rove; this is led through a snatch block to the winding barrel. If a bale is being shipped from the quay it is hoisted above the bulwarks of the vessel by the yard rope. A hatch rope rove through a block suspended between the masts is then hauled taut, and held by one or two turns round a cleat or bitt, the engine slacks off its rope, and the centre of

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suspension is gradually shifted to the hatch rope, the bale swinging diagonally down and inboard, when the man tending the hatch rope lowers the bale into the hold. For discharging cargo the reverse is the action.

Coming to a few details of performances of machines. A boiler, 4 feet 6 inches diameter, of the return tube type, uses 2 cwt. of coal per hour, or 1 ton per day of ten hours. Besides this should be included ½ cwt. to get up steam and one and a half hour's standing at meal times, or eleven and a half hours in all —second quality Welsh coal being used. The Australian liner, *Ethiopian*, was fitted with such an engine, with a boiler 5 feet by 3 feet 9 inches. The coal burnt was at the rate of 2¾ cwt. per working hour, and in fifty such hours 2000 tons of cargo were shipped. On board another ship in the same line 1800 tons were shipped in forty-seven hours. On the Yorkshire, 1345 tons of general cargo were shipped in fifty-eight working hours. The Great Victoria discharged 600 bales of wool in five hours by using a large double-friction winch with cylinders 7 inches in diameter and 10 inches stroke, a boiler 7 feet long by 4 feet 6 inches diameter; the coal burnt was 1¾ cwt. per hour. As to cargo weights, a hogshead of sugar weighs 18 cwt., three of these could be lifted at once, and 500 tons could thus be cleared in nine working hours by steam power. In reference to hoisting gear, the rope employed is usually a 3-inch; when all wound up there would be about one and a half layers on the barrel, which, taking the coil round the barrel to be 2 feet on a barrel 3 feet in length, thirty-four coils added to seventeen second coils for the half layer furnishes a total lift of 100 feet. This limit is seldom arrived at in general work, but is useful if a purchase block has to be resorted to, or under other particular circumstances. The heaviest usual load on such a rope is 35 cwt., but this, as in the case of the sugar hogsheads, is sometimes exceeded.

Referring to speeds of machinery, taking the engine Fig. 3 as an illustration, when distilling it would work about forty to sixty revolutions per minute; when employed, as is sometimes the case, doing heavy pulling and hauling in setting up rigging or heavy work in working the ship, it would be regulated to run slowly according to requirement Whilst weighing the anchor it is usually worked very fast, say 150 revolutions; this would rotate the main shaft say thirty-four times, which would also be the speed of the first motion shaft at the windlass, and it, gearing about 5 to 1 with the second motion, would rotate it in round numbers seven times a minute. This again gearing a pinion to the windlass spur at a ratio of about 3½ to 1, would give it two revolutions a minute. If the ship were anchored in

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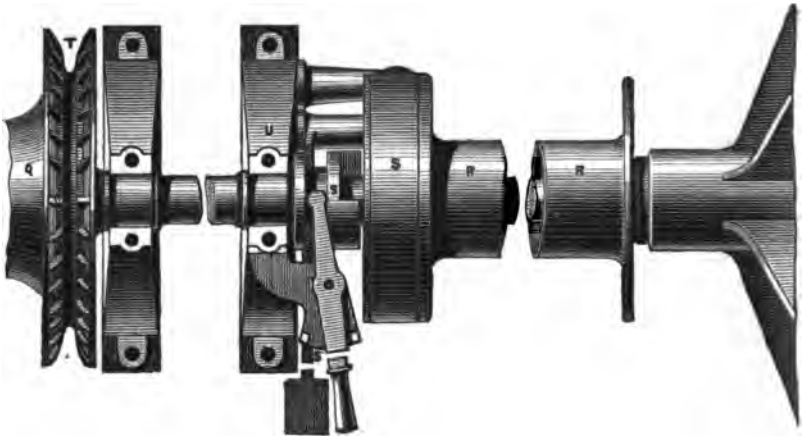
thirty fathoms of water and had out ninety fathoms of cable, the anchor would be brought to the cathead in 30 minutes with a windlass of 3 feet in diameter over the whelps at their largest point. Thus 30 fathoms = 540 feet $\frac{540}{9 \times 2} = 30$ min. The speed of the winding barrel of an ordinary winch is from twenty-five to thirty-five revolutions per minute, taking as an example a friction winch having a pair of cylinders 7 inches diameter by 10 inches stroke, pinion diameter or pitch circle 5½, driving a spur 36½ pitch diameter, gives a ratio of about 6½ to 1; this, at thirty revolutions of the barrel, gives a speed of pinion shaft and cranks of, say, 200 revolutions per minute, though this is often

FIG. 8.



exceeded with light goods. This gives a piston speed at 1·66 per revolution of 332 feet per minute. Such a winch would have a return tube boiler 7 feet long and 4 feet 6 inches diameter. Fig. 8 shows portions of a clutch winch, and explains itself.

Turning now to distillation, allowance of water, &c., the Board of Trade allowance of water, exclusive of that used for cooking, per adult is three quarts per day.* The following is quoted from the regulations of her Majesty's transport service, to be observed in respect of all ships employed by the Admiralty as transports, hired troopships, troop freight ships, convict ships, or store ships:—"1st June, 1866.—Minimum allowance of distilled or filtered water per day per individual, inclusive of cooking, six pints out of the tropics and one gallon within them.

* 18 & 19 Vict. c. 119.

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To suffice for all purposes. Referring to the expense of fuel for distillation the following may be given:—In one case 30 gallons an hour, or 300 in ten hours, was produced by the consumption of 4 cwt. of coal, equalling about 7 lb. of water evaporated per pound of coal, though it must be observed that allowance for a second-class coal on the one hand and the improbability of the amount of distilled water being anything like a close test of evaporation on the other, a higher evaporative result might have been actually obtained, but the author only gives the figures as quoted from his own notes supplied by authorites who had worked distillers at sea. In another instance, 3½ cwt. of Welsh coal distilled 350 gallons of water. Then, again, on board an Australian liner the production of water per day on the voyage to Melbourne was 1600 gallons, from thence to China 1800 gallons, voyage home 1400 gallons. The foregoing data, coupled with the fact that ships having a duly certified distilling apparatus on board can sail with only one-half the quantity of fresh water on board otherwise required by the Board of Trade, which is stored in tanks containing usually 300 gallons each, will enable those interested to judge for themselves of the economy of fitting a ship with a distilling apparatus.

The author, in concluding his paper, will just direct attention to two points. The first is, that although a small and portable apparatus for distilling water and heated by some cheap mineral oil would often be a means of saving life in cases of disaster at sea, if fitted in a ship's life or other boat, he is not aware that any such has ever being constructed, nor has the thing apparently attracted any attention; the only person who ever discussed the question with him being the Rev. Mr. Berthon, inventor of the collapsing life-boat. The second point the author would refer to is as follows:—All engaged in the Australian trade are often put to delay, owing to what is called the calm belt of from three to twenty miles, situate between the northern and the southern trade winds; often here a ship that has made before a rapid progress loses days waiting for any slant of wind to take her out of this region of calm. The author has heard of two liners in sight of each other at this belt for more than a day both becalmed, when one got a lucky whiff that took her to the next trade, while the other was left for two days after her. The author believes efforts have been from time to time made to utilise the steam winch or distilling engine in some way to move the ship on, and he himself designed an engine that could be disconnected from the distiller, and, with its boiler, be placed in a boat and sent ahead to tow.

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DISCUSSION.

The CHAIRMAN called upon the meeting to give a cordial vote of thanks to the author of the paper. He was sorry there were so few present, but he hoped the subject of the paper would be fully discussed. The question of distilling in connection with ships and winches seemed rather a peculiar one; but if it was considered that steam cranes and winches were generally used on board of cargo vessels, and that only when they were in harbour, it was very natural that the idea should occur to the makers to make use of the winch boiler on board ships on the high seas. It appeared to him to be a good arrangement to make use of the small boiler daily for the making of fresh water.

The vote of thanks was put and carried unanimously.

Mr. V. PENDRED (who read the paper on behalf of the author, his brother), returned thanks.

Mr. SCHÖNHEYDER said he thought the paper would be very valuable when printed and published in the Society's 'Transactions,' giving the details of evaporation, coals consumed, &c. He should like to ask Mr. Pendred, on behalf of the author, if it was a fact that the steam which was passed through the engine was the steam which was condensed for water to be afterwards drunk, and whether, if that was the case, any means were adopted to remove the grease that passed through the engine.

A point which was very important in cases of this kind, and which he did not think had been attended to in any of these drawings, was the necessity of removing any priming matter which might pass off from the boiler, inasmuch as that water, if it went off with the condensed steam, would contain all the impurities that were in the water. In describing the winches, he thought it would have been interesting if the author of the paper had given some of the newest winches, viz., winches for hauling wire-rope. Wire-rope was being used more and more every day, even for cables instead of anchor chains. He did not know that it required a special winch, but there were special winches assigned for it. It would be interesting if the author would add these particulars to the paper. He knew that a wire-rope that took the place of a very heavy chain must be of large diameter, and it must therefore not be coiled on too small a barrel. Another point was, that the wire must not be allowed to drop into the hold as chains are, but it must be stowed away in coils round a large barrel or drum.

Mr. GANDON said that the subject was one on which he could not

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say much. He presumed that the condensing apparatus referred to was intended to be used on board sailing vessels. On mail steamers he had seen that the condensed water from the engines that worked the ships was very largely used, not for drinking, but for washing purposes. He had certainly seen a good deal of it, and would not like to drink it in the state in which it had been brought about. He thought, however, that by the use of proper filters it could be rendered fit for drinking purposes. Such condensers as had been proposed would, he thought, be useful for sailing vessels. In steamers, the water to be used could be had from the steam engines. As to steam-winches and windlasses, it was well known how much more largely they were used in vessels where steam could be obtained. He might say that everything on board many steamers was done by steam; they might perhaps some day have a steam captain as well as a steam capstan. He had seen machinery used for hoisting the sails with very great relief to the men, as might be easily imagined.

Mr. SCHÖNHEYDER said he should like to ask the author of the paper if there was any reason for the assertion that 25 or 30 lb. was the best pressure for distilling. It seemed to him that that was immaterial.

Mr. ALFORD remarked that the author had suggested that a ship's boat might be fitted with a propelling apparatus for towing the ship out of a calm. About ten years ago, in Bombay, he went on board of a sailing ship in the harbour. She had a distilling apparatus on board, and the captain had a boom fitted with a swivel from the mizzen chains and surged under the stern. On the end of the boom a small screw propeller was fitted, with a shaft running up the boom and connected with the steam winch in such a way that he could lower his boom down to the water in a calm. By that means he could get a speed of a knot an hour out of the ship, which was sufficient sometimes to get her into a breeze. That seemed to him a fact worth mentioning.

Mr. PENDRED (replying on behalf of the author) said, in answer to the question by Mr. Schönheyder as to the steam passed through the engine, that he was sorry his brother was not present to answer it, because his (the speaker's) acquaintance with the subject was exceedingly small. He talked the matter over with his brother some years ago; but he (the speaker) did not wish what he now said in answer to questions to be taken as absolute fact. The questions that were asked him he should submit to his brother (the author of the paper). He would put the various questions that had been asked to the author, who

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would answer them in due time. As to the passage of the steam from the engines through the condenser, at the time the steam was being passed through the engine, as the engine was doing no work whatever but moving the circulating water, no lubrication was used. The pressure used was exceedingly small, 8 to 10 lb. to the square inch; but the engine had been working for some little time. Then distillers at sea on board sailing vessels were worked continually when days were calm. Some days, when the wind was blowing hard, the distillers could not be worked, or they could not be worked unless under difficulties. If they were put on deck, and in exposed places, there was a great difficulty in working them, and he was astonished that more attention had not been paid to the placing of these engines. If deck-houses were constructed, they could be used no matter what the weather was; but he believed that what was objected to was purely the matter of expense. As to priming, priming, he might say, had been the ruin of more than one distilling system. There had been a great many of this sort of apparatus brought forward, and they had come to grief because the priming water could not be got rid of. The paper had alluded to the fact that if the boiler illustrated had got two steam domes or two steam boxes on the top, and the steam from the boiler was taken from the one and then led to the other, a pipe in the second led away condensed water, the pipe descending below the level of the water within the boiler; then, in that way, all the priming was practically kept out of the condenser; nothing got over. The condensed water, when drawn off, was allowed to fall from a height of three or four inches, carrying the air with it. If that precaution was not taken, the distilled water was flat. He had tasted it, and it was the most disagreeable thing anyone could taste. It was wonderful what a difference aëration made in it. As regards winches for wire rope, he might say that he did not know anything at all about them. He had first heard about them that evening, but he would mention the matter to his brother, who, he had no doubt, would supply additional information to that given in the paper. As to whether 25 to 30 lb. was the best pressure, he could not say, that was the pressure given by the makers; but it did not seem to him that that was any better pressure than any other. Mr. Gandon had asked a question in reference to sailing-ships. He (Mr. Pendred) might say that in a very large number of steamships the apparatus in question was fitted. All the Government troop-ships had got a special apparatus; for this reason, that although fresh water was obtained from the boilers, water was obtained which was very unpleasant to drink.

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It was practically unsuited for use unless one were driven almost to die of thirst. It was not only that it was greasy, but it had a very peculiar smell or odour, which was particularly objectionable. Nearly all the old boilers working with salt water had got a condenser fitted to them. It was simply a copper vessel. It was fitted at the ships side in a place where it would be tolerably cool, and steam was taken in at the top. In this there would be found distilled water, which was used by the engineers, and others, and there was nothing objectionable about it; but that could scarcely be used in the present day. As to what Mr. Alford said with regard to a ship being becalmed, and the use of a small screw at the end of a spar, he (the speaker) had no doubt that it was a clever device; because when a ship was becalmed a very small force would pull her out of the doldrums. Sailors, as a rule, like to lie quiet, and did not like towing in a boat, if they could avoid it. Speaking for himself, he thought that the origin of the system of distilling on board ships was rather curious. He believed that the first account of distilling at sea was to be found in the Annual Register for 1772 or 1774. The story was told them of a ship's captain coming home from the West Indies. His ship was becalmed, and when the crew ran out of water, and were at their wits' end, the captain got some boards and made a lid for one of the ship's coppers, fitted the lid well, and made it tight at the edge with paste and old rags well wedged in all round. To make a pipe for a condenser, he cut up the pewter dishes of the cabin, hammered them round so as to make a pipe, which he passed through two holes, bored one at each side of a cask. Salt water was put in the cask, and when the fires were lighted the water in the copper boiled, the steam in the pipe was condensed, and fresh water ran from the still. When the captain came to taste it, he found the water was very abominable. The fact was, he (the captain) did not know what to do to purify the water; but he thought it was exceedingly flat and tasted bad. He mixed a little salt water with it and that slightly improved it. He (the speaker) did not know what the connection of ideas was in the captain's mind, for nothing was known of the use of charcoal as a disinfectant at that time. He found, however, that the water was unpalatable. He took billets of wood from under the ship's copper and put them into buckets into which the water ran, allowed the water to stand on those billets of wood, then poured it out and found that it was drinkable and could be used. Thus they had actually got a description of the whole system of distilling and purifying water more than a hundred years ago,

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which was adopted on board ship. There could be no doubt at all as to the antiquity of the process. Supposing the story was untrue, those who had written an account of it must have had a clear conception of how the thing was to be done. It was given as an extract from the ship's log. There they had the distilling of water at sea and the purification of water by charcoal at the same time, which was remarkable as well as interesting. There was another point which struck him as interesting. It was very well known that the best boilers that could be obtained, would not evaporate more than 12 lb. of water per pound of coal, as in the ordinary Lancashire boiler; it would not evaporate more than 8¾ lb., 9¼ lb., would be very much beyond the ordinary performance. But it was a fact that Dr. Normandy, with his distilling apparatus, had produced from 22 to 23 lb. of distilled water with each pound of coal. At first it seemed absolutely impossible that anything of the kind could be done; but it could be seen in a moment how the work could be accomplished. When the statement was first made to him, some eight or ten years ago, he could not believe it. Dr. Normandy worked the steam at very high pressure—60 or 70 lb. per square inch—to begin with, and he condensed the steam in a vessel which was itself a boiler, and the process of evaporation was done three times over. It would be seen that in the act of condensing the first volume of steam the heat surrendered would readily evaporate another lot of water, by keeping the temperature of the condenser sufficiently high. That actually had been carried out, so that there was an evaporation of 14 or 15 lb. of fresh water per pound of coal burnt, and there were other cases of 22 to 23 lb. of water.

Mr. SCHÖNHEYDER said it was the same "Triple effect" system as was used in sugar works.

Mr. PENDRED replied that it was.

The CHAIRMAN wished Mr. Pendred to convey to his brother the purport of the various questions that had been asked in reference to the paper, and to express the pleasure with which those present at the meeting had listened to it.

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June 7th, 1880.

JOSEPH BERNAYS, PRESIDENT, IN THE CHAIR.

ON SENSITIVENESS AND ISOCHRONISM IN GOVERNORS.

By ARTHUR RIGG.

As the only real object of a governor is to secure regularity in the speed of an engine, it becomes an interesting inquiry how far this result is accomplished by the sensitive governors now so frequently in use.

All disturbing elements which affect the regularity of an engine may be divided into two classes. Those self-contained, which are principally due to periodical variations in the tangential effort on the crank, and those outside, which may be concentrated into irregular or periodical variations in load.

Inherent irregularities are modified—1st, by the equalising influences of reciprocating parts on the irregular steam pressures shown by an indicator diagram; and 2nd, by the inertia of rotating parts, especially the fly-wheel, opposing changes in velocity.

The influence of reciprocation may be conveniently shown by simply transforming an indicator diagram, remembering that steam pressure absorbed in giving acceleration to the piston, motion block, and connecting rod during the earlier half of each troke, is restored as pressure on the crank-pin during retardation in the later half.

Thus, an indicator diagram, such as shown by the full line A B C D E, Fig. 1, so transformed, become modified into a direct pressure from the piston upon the crank, according to the shaded figure W X Y Z E, and the rotative tangential effort is shown by radical ordinates measured from the circular base or crank-path A E B F, Fig. 2, to points on the curves A C B D A; the zeros A and B corresponding to the terminals of each stroke.

The influences of all rotating parts of any engine may be conveniently concentrated as at the fly-wheel rim, and the work absorbed in accelerating, or given out by retarding this rotating mass, is the first moderator of all self-contained irregularities of an engine's movement, quite apart from the governor balls, which can only act while steam is admitted.

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If a circle G L H K be drawn at such a distance around A E B F as to represent a uniform resistance (exactly equal in amount to the irregular driving power), it is easy to see that during those parts of a revolution where the driving curve projects, an increase of speed must take place, and where the retarding element predominates, speed reduces; the sum total of increase and decrease per revolution being in every case a constant. For if this be not so, then an engine goes faster or slower.

Either greater mass, or increased velocity in a fly-wheel, enables it to absorb all irregularities due to the varying pressure from which its motion takes origin with less variation in its own rate, that is to say, the ratio of variation in speed will be less in

Fig. 1.

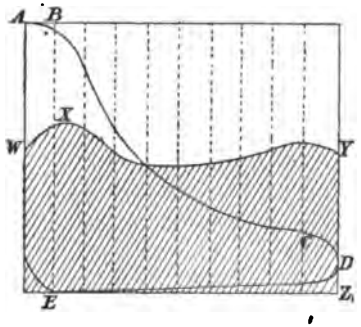
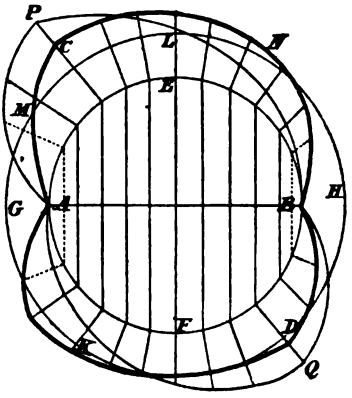


Fig. 2.



the case of a heavy fly-wheel, or in one that runs at a considerable velocity, than with a light or slow moving fly-wheel, with a given excess of pressure or resistance. But before these differences can reach the fly-wheel, they are to some extent reduced by elasticity in the main shaft; but being always present, it follows that an absolutely uniform speed in the motion of an engine is unattainable.

The rate of variation is ascertained for any case by constructing such a diagram, W X Y Z E, as shown by Fig. 1, and the transferring excess or deficiency of pressure into the form of a diagram similar to Fig. 2, then, if the largest area be that enclosed by M C N, representing in this case an excess of pressure over resistance, the measurement of its area, like an indicator diagram, gives the mean pressure acting on the fly-wheel during a time occupied by a movement from M to N. So it is easy to ascertain the increase of velocity in a fly-wheel

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of known mass, and thus the periodical variation in speed. The curve A P B Q represents the direct action of the indicator diagram, without being modified by the influence of reciprocating parts.

In engines such as the agricultural class, the variation is very considerable, but in engines of good proportion it may amount to less than one hundredth of the mean speed.

With coupled engines having cranks at right angles, the equalising influence of reciprocation is neutralised, because all pressure required for the acceleration of one piston is provided by retardation of its companion, and so the indicator diagram practically represents direct pressures on the crank, so such an engine may exhibit even greater variation in its power and speed than one having a single cylinder, and with its proportions well arranged throughout.

No governor can compensate for periodic changes in the rate of an engine, such as occur during every revolution, and therefore its sensitiveness should be limited, so as not to notice the regular variation which is designedly permitted beyond the mean speed. Innumerable examples exist where this consideration receives no attention, and a sensitive governor is seen applied to an engine totally unfit for such refinement. It is perpetually in motion, and causes more irregularities than it ought to cure, so that a common-place engine works far better with an ordinary governor than with the complicated apparatus often provided. For its balls are heavy, unready at responding to variation in speed, and their inert action suits engines where the inherent variations are considerable.

While one engine may vary its rate one tenth, and another only varies one hundredth, on either side of the mean speed, it is clear that a more sensitive governor may be applied with a nearer approach to isochronism in the latter than in the former case.

The superior uniformity in speed of beam engines, as compared to many of the horizontal form, is due to the inertia of their heavy moving masses of metal, which modify the slight irregularities of steam pressure to which they are subjected, and permit of their being governed with regularity. But in horizontal engines, generally of cheaper construction, and having lighter moving parts, there is not such capacity to absorb and modulate the irregularities of driving power, and consequently such engines do not work so steadily at ordinary speeds. A very simple remedy for this evil is found by an increased rate of revolution, which reduces the inherent irregularities to an extent which enables horizontal engines of proper design to compare most favourably with engines of any other type.

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All irregularities external to an engine may be considered as changes in resistance, and illustrated by altering the form or diameter of the load circle G L H K, Fig. 2, Their incidence must at first be counteracted by inertia in the reciprocating parts and fly-wheel, and if their duration becomes prolonged, the governor can act by causing admission of steam, and increasing (or diminishing) the moving force until an equilibrium is re-established between power and resistance.

Where the supply of steam is tolerably constant through a greater part of the stroke, which is practically the case with compound engines, it is evident that the governor has greater opportunities of regulating the admission, than with engines working at high rates of expansion in a single cylinder. The latter class requires already greater momentum in their moving parts, owing to internal changes of driving power, so that still additional momentum is needed to carry the engine over changes in load which may occur after expansion of steam has begun.

It may therefore be concluded that inherent periodical irregularities in the driving power of an engine should be so sustained by moving masses as never to affect the governor, and that external variations in load should first slowly alter the rate of moving masses, and the governor then be called upon to exercise its proper function.

The common governor, a double conical pendulum, varies its rate of revolution in proportion to the height of its point of suspension above its plane of rotation, and the subjoined Table gives the vertical height of cones of rotation with corresponding speed for convenient reference.

Height in Inches.	Revolutions per Minute.	Height in Inches.	Revolutions per Minute.	Height in Inches.	Revolutions per Minute.	Height in Inches.	Revolutions per Minute.	Height in Inches.	Revolutions per Minute.
4	94·	10½	58·	17	45·56	23½	38·75	30	34·30
4½	88·70	11	56·65	17½	44·90	24	38·33	30½	34·02
5	84·01	11½	55·41	18	44·24	24½	37·95	31	33·74
5½	80·21	12	54·23	18½	43·48	25	37·57	31½	33·47
6	76·70	12½	53·15	19	43·10	25½	37·20	32	33·21
6½	73·76	13	52·11	19½	42·55	26	36·84	32½	32·95
7	71·02	13½	51·14	20	42·00	26½	36·48	33	32·70
7½	68·63	14	50·21	20½	41·49	27	36·15	33½	32·46
8	66·42	14½	49·34	21	40·99	27½	35·83	34	32·22
8½	64·46	15	48·51	21½	40·48	28	35·50	34½	31·98
9	62·62	15½	47·72	22	40·05	28½	35·19	35	31·75
9½	60·99	16	46·96	22½	39·60	29	34·88	35½	31·53
10	59·41	16½	46·23	23	39·17	29½	34·58	36	31·31

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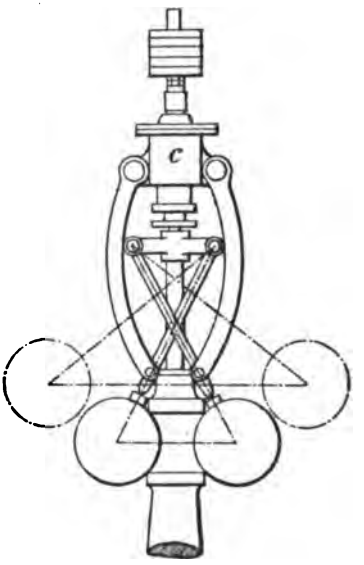
The cross-arm governor, Fig. 3, is adapted from the isochronous parabolic type, and may be arranged so that its point of suspension remains at a constant height, or at any variation from a constant height, above the plan of rotation, and a true or approximate isochronism be brought into play along with considerable sensitiveness.

High speed loaded governors, though far from approaching isochronism, are generally found to exhibit the character of sensitiveness in consequence of their balls being light, and responding readily to all periodical changes in an engine's movement. It is no uncommon thing to find such a governor in a permanently excited, unstable condition, and speed irregular, through the spasmodic uncertain manner in which steam is admitted or excluded.

Fig. 3.



Approaches towards isochronism are accompanied by excessive sensitiveness, and to diminish its evil effect, while retaining such an approximation as may be practically workable, is a necessity which has been laid upon the inventors of all the higher classes of governors now in general use.

Many such governors are driven by a long elastic belt, which to some extent absorbs and lessens the effect of momentary irregularities by the time they reach the governor. Apart, however, from the dangerous nature of such an unreliable connection, from which serious accidents have been known to arise, it is too much a makeshift to be regarded as a scientific remedy for an admitted evil. The well known cataract cylinder has been used in different forms for diminishing the sensitiveness of governors, without preventing their assuming any position within their range at a given rate of motion. In the example given by Fig. 3, the cylinder C serves as a load, resisting centrifugal force; and it is filled with creosote or oil, while the piston is attached to the verticle spindle, and by regulating a bye-pass cock any desired hinderence may be placed against

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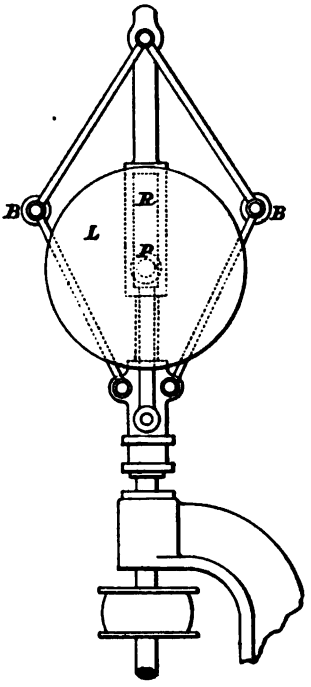
movements of the governor. The weights carried upon the cylinder serve for any exact regulation of speed.

In this example, the height of cone when the balls are down is 10 inches, corresponding with 59·44 revolutions, and when the balls are raised to their highest position the height of cone is 9 inches, corresponding to 62·63 revolutions per minute. Hence the mean rate of 61 revolutions is subject to a total variation of 3·19 revolutions, or 4 per cent on each side, and to that extent is this governor removed from a perfect isochronism.

Fig. 4.



The rapidly rotating loaded or "Porter" governor has secured very general popularity, owing to the ready response of its light balls to changes in velocity. Any excessive sensitiveness is moderated by the inertia of its load, and by the elastic driving belt, but it would be generally desirable to provide an arrangement of some description to delay its movement more effectually.

Fig. 4, illustrates a new method for reducing the sensitiveness of governors, where two light balls B B′ rotate rapidly, and by their centrifugal force raise a load L. Here, the load is constructed in two fly-wheels L L′, which have a spur pinion P keyed between them, gearing into a fixed rack R, thus the two fly-wheels are compelled to roll round as they are raised or lowered, and their inertia has to be overcome before the balls can move, and so an inconvenient sensitiveness is prevented.

In this method for diminishing sensitiveness, there is a definite resistance, which seems more reliable than a cataract, without any risk of failure by disarrangement of the machinery or escape of the enclosed fluid. Thus it would almost seem that any governor possessing such modified sensitiveness or isochronism remains finally in much the same condition as a fairly sensitive governor of the ordinary type, only possessing

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superior mobility, and being better able to overcome resistance through the power developed by variations in the high velocity of its balls, but such a conclusion is not sustained by further consideration. In ordinary conical pendulum types, the speed must vary considerably throughout the range, and an engine is bound to run at very different rates at different positions of the balls, but in the more isochronous types, their range of movement may be great, and yet the engine vary but little in its speed at whatever position the balls may stand. The isochronous type, being thus most efficient, provided its rate of movement be not inconveniently rapid.

Direct-acting Governors.

This modern class of governor acts directly upon an eccentric by moving its centre to different positions relatively to the crank; and a valve is driven by such variable eccentric, to cut off steam within any desired range. The governor ball, or balls, revolve with the engine shaft, partaking of its every variation in speed, their centrifugal force alters in direct proportion to the distances between the centres of motion, and centres of gyration at any constant speed; and if the spring which controls the movement of such governors be designed so that its compression exactly corresponds to the centrifugal force, a perfect isochronism is secured. But this is accompanied by such an excessive unsteadiness, that it becomes necessary to strengthen the spring, and remove its proportions very far from isochronism, in order that the governor shall work at all.

This position of things in a direct-acting governor corresponds, with the common type of conical pendulum, where a great variation in speed accompanies its several positions, and any increased sensitiveness is met by the same difficulties which occur under similar conditions with governors approximately isochronous, difficulties aggravated, however, by the positive and rigid manner in which every variation in the speed of an engine is communicated to the direct-acting governor.

Under the conditions of its construction, a cataract would be inconvenient of application, and therefore another system must be adapted to cause a response to changes which occur in the load, of any duration, without the governor being influenced by momentary changes.

After many experiments, the author has discovered a method which seems to answer the desired end satisfactorily, enabling direct-acting governors to be constructed to move without excessive oscillations, and yet be sufficiently sensitive and

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isochronous as to secure uniformity of motion. According to this plan, the governor ball, or a part of it, is caused to rotate while moving; and the effect is similar to the rotation of fly-wheels applied to rapidly moving governors as already described and illustrated by Fig. 4. The inertia thus overcome prevents the governor being influenced by periodical variations which accompany every revolution, and yet permits sufficient sensitiveness to changes in load. This system has been carried out in several ways, but perhaps the most practically useful form is illustrated by Figs. 5 and 6. This is a drawing of a patent

FIG. 5.

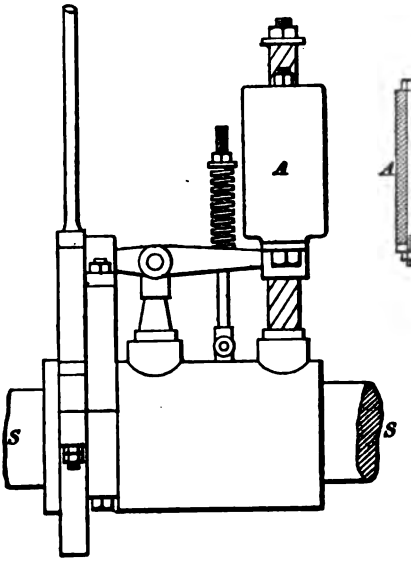
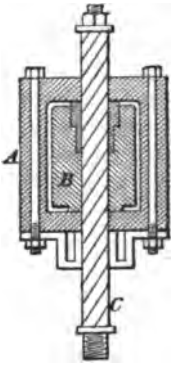


FIG. 6.



governor in use upon a horizontal condensing engine running at 160 revolutions per minute; having a 14-inch cylinder and 21-inch piston stroke, worked by a pressure of 90 lb. per square inch, and developing about 70 indicated horse-power.

The "ball" which provides centrifugal force consists of a frame A enclosing a heavy nut B, both guided by a spindle C, fixed radially to the engine shaft S, and on which is cut a spiral thread. When the ball moves in or out, the nut is compelled to rotate upon the spiral screw, and the time required by centrifugal force to overcome its inertia retards what would otherwise be an inconvenient sensitiveness. The influence of inertia is so

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powerful that even a single unbalanced ball can be made to govern an engine with very tolerable regularity.

Whenever delicately adjusted governors are employed, their reserve of power is very small, and any cut-off valve they regulate should be easy to move, so as not to throw on their centrifugal force a load which it cannot fairly be expected to sustain. By neglect of this precaution, the governor ball has to accumulate sufficient energy to overcome the resistance, and then flies to an extreme position and continues oscillating, so causing great irregularity in the supply of steam, and consequent rate of speed.

The Relay System.

Whenever a governor directs the action of an independent power to do certain work, the system becomes one of "relay," and this is a plan in one form or another applied to many modern high class engines. By an imperfect application of this system the governor moves a link, determining the stroke of a valve, and so fixing the rate of expansion. A more perfect example of relay is the well known plan where a governor raises or lowers a pair of flat discs, which gear into or release a third disc, and so alter the position of cams, or perform any desired movement requiring power.

But perhaps the most efficient relay is where a governor opens a valve to admit, exclude, or release hydraulic pressure to or from a cylinder; and by this plan very considerable power is available, and under ready control. This relay is often applied to such work as moving the regulating sluice of a turbine, and so controlling its supply of water, but such governing arrangements, when not in constant use, are liable to become unserviceable. To remedy this inconvenience, the author employs a simple modification, which serves also as a good example of the relay system of governing. In Fig. 7, the sluice S of a turbine is moved by a lever in connection with an hydraulic plunger P. Admission of water pressure raises this plunger, and opening an exhaust valve allows it to fall by its own weight. When in the position shown, a double cock C closes all inlet, and permits egress of water from under the plunger, but when this cock is turned at right angles to the position shown egress is closed, the inlet opened, the plunger rises and opens the circular sluice, so the turbine rotates until the governor closes further inlet, by raising the equilibrium valve V, and so preventing the sluice opening wider.

If work is now added, the governor falls, admits more water

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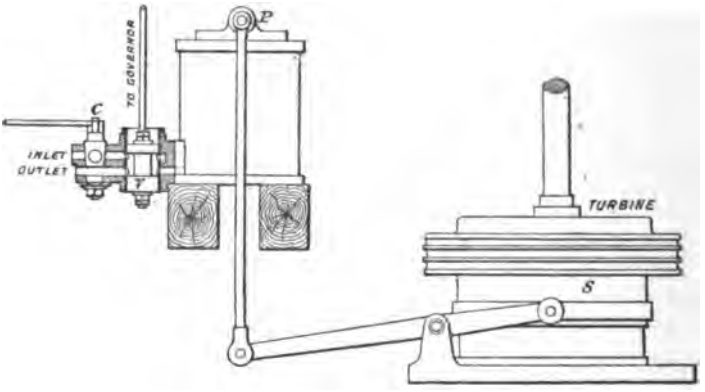
under the plunger, and so the sluice opens until the governor occupies its mean position, and equilibrium is established. If the load is reduced, then the governor rises, first closing inlet of water, and by further movement opening a new outlet, and the plunger descends until the governor occupies its mean position. If the hand cock be reversed, a new outlet permits an escape of water, so that the hydraulic plunger descends and closes the sluice altogether.

This combination of starting cock and governor is kept in constant use, therefore always in working order, and it is found very efficient.

A relay system in the Corliss engine consists of a trip gear,

Fig. 7.



so that the governor has no actual work to perform, but only to decide where a trigger shall be released, and steam cut off. This system works well at a moderate speed, and has met with very considerable success since its first introduction.

By the relay system, a small movement in the governor can effect to any desired extent the regulation of an engine, and a very moderate sensitiveness determines uniformity in the speed of an engine.

In conclusion, it seems that any approach towards isochronism is accompanied by excessive sensitiveness, and, unchecked, would require abnormal development of inertia in the moving parts of an engine to prevent unsteadiness in the governor and irregularity in speed.

In order that the movements of an approximately isochronous governor shall synchronise with the amount of regularity

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practically attainable by an engine, it is necessary that its sensitiveness shall be moderated. This may be done by the system of cataract, or by an application of inertia to the governor, which shall cause its movements to work in unison with the inertia of moving parts of an engine.

By thus making sensitive and approximately isochronous governors to work harmoniously with an engine, the greatest attainable regularity is securred.

DISCUSSION.

Mr. Schönheyder said that the paper they had heard was not only interesting but full of valuable data, and required almost to be read over again before being discussed. There were portions of the paper, however, which ought to be either corrected or qualified. Mr. Rigg had spoken about the speed of the governor being measured by the height from the plane of revolution of the balls to the point of suspension. That was not strictly correct, though Mr. Rigg, no doubt, meant what was right. The speed was calculated by the height from the plane of revolution of the governor balls to the point of intersection of the arms with the spindle, which often made a very great difference. He remarked on that point, because it was a common mistake to measure the height of the governors from the point of suspension to the plane of revolution, and men got into mistakes by doing so. In the cross-arm governor, of course, they measured the height from the point of intersection of the cross arms to the plane of revolution of the balls. He thought the whole matter had been very fairly put before them, and they must consider it an exceedingly valuable paper. The whole method of measuring the variations of power of engines, as given in Figs. 1 and 2 had been so clearly put that everyone ought to understand it. With reference to Mr. Rigg's new governors, he rather expected the governor in Fig. 4, if it had the advantage of meeting with a certain amount of resistance to too quick a movement, would also have the defect of continuing to move after it ought to have stopped moving. The inertia of the fly wheel, which had to be overcome in the first instance to allow the governor to lift, would also act in a prejudicial manner by continuing to act when it really ought to stop. The governor would go beyond its stroke, and move the valve to too great an extent. If Mr. Rigg had tried the governor shown in Fig. 4, he would be glad to know if any such defect was found. The same remarks applied, to a certain extent, to the governors shown in Figs. 5 and 6, that the weight

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B might continue to revolve after it ought to stop. In that case, however, they had the friction, which tended to stop it, and if Mr. Rigg had tried that governor, he would like to know whether he had found any defect arise from the amount of friction which must necessarily take place between the nut and the spindle, whether he had found that friction to retard the working of the governor to too great an extent, and reduce the sensitiveness more than it ought to do. The paper had spoken about governors racing, and causing the engine to go unsteadily. That might be the fault of the governor, or it might be the fault of the engine. One very common cause of governors racing was the making of the throttle valve too large, so that ordinarily the valve had to be almost closed. If with such an arrangement the load on the engine was increased so that the governor went slower, and began to open the throttle valve, a small opening of the valve gave an excess of steam, and the engine flew off too fast, then the governor checked it, and shut of the steam entirely, and so on. A large throttle valve caused a certain amount of racing, especially if combined with a certain amount of slackness of the gear between the governor and the throttle valve. He had repeatedly found that to be the cause of racing. He would imagine that in the arrangement given in Fig. 7, something like the same would take place. He did not quite see how the movement of the water cylinder P was to be arrested. Suppose the turbine went too fast, and the valve V was moved so as to admit water underneath the cylinder P, that water would continue to flow through, and raise the cylinder until the supply was entirely shut off from the turbine. There seemed to be no kind of regulating means for the purpose, unless the cock C was regulated.

Mr. RIGG said there was another regulator, which was not shown on the diagram.

Mr. SCHÖNHEYDER said he had seen a similar arrangement applied to a 1000 horse-power engine, in that case there was a "Myer" expansion gear operated in a similar manner, and the screws of the expansion spindles were acted upon through a rack driving a pinion; and the effect of the arrangement was that as soon as water was admitted to the bottom of the hydraulic cylinder so as to alter the expansion, the rack flew up to the top and altered it too far; and the moment the water was admitted to the top of the cylinder the rack flew down to the bottom again; and so was continually moving from top to bottom. A regulating means was wanted for checking this racing.

Mr. HALPIN said that what Mr. Rigg had said in regard to

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governors, as to their division into two classes, was true. The advantage of using governors actuating any kind of tripping gear was that they had nothing to do, and as long as that was the case they did it very well. That was practically the case with the old form of Watt governor, which only worked a throttle valve, almost without friction. In all the later governors, attempts had been made to make them drive expansion valves, and, as he knew from personal experience, a great deal of the failure had arisen through the governors not being powerful enough to do their work. He had been formerly under the delusion that a governor was artful enough to wait till it had nothing to do, and then it did it; to wait till the engine was at such a part of the stroke that the expansion valve was not moving, and that then the governor would make the move and lock the expansion gear in the new position. But he found that that was not so. It was only by putting plenty of mechanical power that they could get satisfactory results with the expansion valves that were chiefly used.

The CHAIRMAN said he thought it was stated in one part of the paper, that the governor was generally used for regulating the differing speeds that occured during each revolution of an engine.

Mr. RIGG said no, it could not be used for that.

Mr. SCHÖNHEYDER said he wished to ask Mr. Rigg whether it would be within the scope of his paper, if he were to add a table of the power that certain governors possessed, that he (Mr. Rigg) had tried; by the power, he meant the foot pounds of energy the governors would accumulate with a given variation of engine speed, so as to show which was the best governor to overcome certain resistances. It was a very interesting point.

Mr. F. E. DUCKHAM thought the governor in Figs. 5 and 6 an awkward thing whirling round on a shaft, and asked whether it could not be shielded by being made part of the fly-wheel, or by some arangement which would place it out of danger both to itself and to the engine attendants.

The CHAIRMAN asked whether the spindle went round with the shaft.

Mr. RIGG said that the whole arrangement was keyed upon the engine shaft S, and went round together. The model he held represented a slightly different governor to the diagram, but the same principles were involved in both constructions. The eccentric might either work a slide valve or an expansion valve, and although there were many different ways of altering an eccentric, so as to regulate the position where steam should

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be cut off, yet the plan of altering its stroke is the one he preferred, for if the valves be arranged for the normal rate of expansion they gave a very sharp cut off. With regard to Mr. Duckham's remark, as to the necessity of some guard around the governor, as a matter of fact a pulley surrounded it, and the apparatus was thus inside and protected, so that it was not as dangerous a thing as the model might lead one to imagine. He was much obliged to Mr. Schönheyder for his remarks, as few were more competent to discuss questions of governors, and he would do his best to reply. In measuring the point of suspension in "pendulum governors" from the plane of rotation Mr. Schönheyder was perfectly right, the cone should be measured from the point of intersection; with a vertical spindle to the plane in which the balls rotate, and in cross-arm governors the point of suspension rose and fell as the ball rose and fell. That was how isochronism in those governors is obtained. Mr. Schönheyder had also suggested that the fly-wheels shown in the quick-speed governors might go too far. He had not done much with such governors, but he found that very little motion was necessary to give the required retardation to their movement. If the apparatus were made too heavy, the fly-wheel did over ride, and cause the governor balls to run up and down, and they required a careful adjustment. In that form of governor shown by Fig. 5, the nut was comparatively small, or rather it was long and close to the spindle, and its rotation comparatively small, producing so little momentum as not to cause the evil which Mr. Schönheyder correctly argued would be the effect of disproportion in these parts; even with difficulties caused by incorrect adjustment he got a fair regulation, as good as could be got with the ordinary governor. As Mr. Halpin had suggested, a more powerful governor gives a superior result. To remove friction, rollers or balls are inserted like those on a lifting jack, otherwise the twisting strain might stop the apparatus altogether, and friction rollers enabled it to work easily. With regard to the unsteady motion being the fault of the engine or of the governor, what Mr. Schönheyder had said about too large throttle valves was right, but in writing the paper he had only noticed the one difficulty, and there were so many others to contend against that it would be too long to enter into and discuss them in a single paper. Mr. Schönheyder had also asked about a table of the amount of power in different governors, and on this subject he would mention having made a machine to measure the amount of power, but it was so much trouble to adjust it, that he had found it much easier to make the calculations and regulate finally by experiment.

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Mr. Halpin said that governors which had nothing to do, were most satisfactory, and he was quite right. Evidently the more power and centrifugal force they gave to the governors so much the more easily would they move, especially against a moderate resistance, but any accumulation of energy necessarily destroyed isochronism.

The question was asked for what power engine was a governor of the size shown by the diagram intended.

Mr. RIGG replied that the particular one was on an engine with 14-inch cylinder, now working at 80 indicated horse-power, but capable of doing more, and the governor ball was about 70 lb. weight.

The turbine governor, Fig. 7, was drawn full size. It required careful regulating, or else the ram ran up and down, and no uniform speed was obtained. In order to regulate it, he had used, between two flanges, a disc of iron, and a hole $\frac{1}{8}$th of an inch diameter would serve for a governor of that size to let the current of water through. They must never have a very sensitive governor for such an arrangement, because a small motion opened or closed the valve, and one of the common ball governors acted well.

The CHAIRMAN said that Mr. Rigg had so fully answered all questions raised, and had had so much experience, that he himself could add nothing. His own experience was of long ago, and really referred to the ordinary governors. He remembered a case in which they used such governors to work and regulate an expansion valve. The expansion was altered by varying the length of stroke of the valve, and was in the way of a link, being pulled in an out over the spindle. The governor was a heavy Watt governor, and the sleeve carried two discs concentric with it, and between the discs, which were apart, there was a vertical disc carried on a horizontal shaft, with a screw cut on the latter. This, going to the right or left, pulled the link forward or back as the governor rose or sunk. They had a curious experience with this. They allowed the two discs of the governor sleeve to have at first an inch clearance before they touched the other disc, and found that this would not regulate the other engine at all. The governor would get such a speed on that it would go right up, and then it had such a momentum that it kept the discs in contact for a considerable length of time, pulling the link right on to its outer end. The engine would then stop, or almost stop, before it went on again. They had no power of regulating that engine until they came to reduce the distance between the discs, so that the governor could only move $\frac{1}{16}$th of an inch in either direction, and then it

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managed very fairly. They set the governor to its mean speed, and made the intermediate disc as large as they could, leaving $\frac{1}{16}$th of an inch space, and then the engine worked very fairly. Since then many other governors had come up, quick-speed and direct-acting governors, and he had no doubt that with the governors brought forward by Mr. Rigg, very good regulation was now brought about. The relay governors seemed to have taken the fancy of everyone, for the reason that they were very powerful in comparison with the work they had to do, and that they managed to regulate the engine very perfectly just at the moment when it was necessary, that is before the speed of the engine was greatly altered.

The Meeting then separated.

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THE VACATION VISITS.

SPEECHES AT DINNER AT THE CRYSTAL PALACE ON THE SOCIETY'S VISIT TO THE SOUTH METROPOLITAN AND CRYSTAL PALACE AND DISTRICT GASWORKS, THE 29TH OF JUNE, 1880.

After dinner, the president, Mr. Joseph Bernays, proposed the health of the "Queen and Royal Family." He said that it was unnecessary that he should dwell on such a topic; the toast was one always cordially responded to. He might, however, refer to the fact that the Prince of Wales had just opened a great harbour at Holyhead and the Llandudno Waterworks, while his brother, Prince Leopold, has opened a very magnificent work which had once proved the object of one of their visits, namely the Victoria Dock.

The toast was drank with the usual honours.

Mr. Bernays next proposed the health of their "Guests," coupling the toast with the names of Mr. Livesey and Mr. Gandon. They had, he said, passed a most pleasant and instructive morning, and they were much indebted to Mr. Livesey and Mr. Gandon for the trouble they had taken to show them much that was of the greatest interest. Everyone used gas, but everyone did not know much about how it was made. That day's work would go far to remove this ignorance, and, apart from gas, the great gasholder now in course of construction, which they had seen with its concrete-walled tank, afforded an admirable subject for examination by engineers.

Mr. Livesey said he was much obliged for the very cordial way in which his health had been drunk. If the visit paid to his works had given satisfaction to the Society it had given him much more. He attached much importance to these visits, because of the great advantages which they must prove to the younger members of the profession, who had thus opportunity of seeing works which they could not hope to get in any other way. He had not expected to be asked to such a banquet; the South Metropolitan Gas Company had not, perhaps, much to show. But it was worth notice that they had seen there a portion of the works which were fifty years old; these stood on leasehold ground, and until they succeeded in buying it they did not intend to make many alterations, but they would soon be

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remodelled. In a word, his view was, that a first-class gasworks should be a perfect machine for making dividends. He did not hold with spending much money on decorative adornments, which in any case were soon discoloured and spoiled by smoke. He was determined to adopt all possible improvements, and although we were well up with the day in some respects, yet in others France and Germany were ahead of us, using, as they did, Siemens' gas furnaces to heat the retorts, with a great saving of fuel, and more gas was got out of each retort in a given time; much ingenuity was required to apply the principle to the required end.

Mr. Gandon said that he had really nothing to add to the eloquent speech they had just heard from Mr. Livesey. He would only say that they had seen all he had to show, and that he would be delighted to give information at any time to members of the Society of Engineers who wished for it.

Mr. Livesey then proposed the "Success and Prosperity of the Society of Engineers," which showed admirable vitality. Mr. Williams was in a very large sense the founder of the Society, and had done much to promote its interests; one of the great wants of such societies was plenty of papers. Nothing taught a man so much of a subject as writing a paper about it. Most men wanted inducement to undertake the labour, and they ought to be pressed by the Council until they consented. He held that the Society of Engineers owed much of its prosperity to the practice of visiting works, which enabled many men to see, touch, and handle that which they knew of before only as a drawing. As regards papers, he would like to see the Members describe failures, which were more instructive than successes. He had done this himself, and had been received with the greatest kindness and the fullest appreciation of the merits of the plan. Any one might meet with a failure in his practice and descriptions of such failures were of the utmost value as warnings to others. He concluded by saying that he had made Mr. Bernays' acquaintance with much pleasure, and he felt certain that in such hands the Society must flourish.

Mr. Bernays said, in reply, that the honour done him by Mr. Livesey was due not to him, but to the Society. He was glad to hear Mr. Livesey endorse his views about reading papers. Nothing taught a man so much as teaching others. The Society had great vitality, he was glad to say, and he hoped in a few years it would be at the top of the tree.

Mr. Pendred proposed the health of Mr. Williams, to whom the Society was under great obligations; whenever Mr. Williams was absent from the Council table it might be taken as certain

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that all was going well, but the moment the ship got into troubled waters, Mr. Williams, was at the helm, and aided to guide the ship into port, with the most indefatigable energy.

Mr. Williams, in reply, said that he had been connected with the Society from its earliest days, and that, with the assistance of the Council and all concerned, he hoped it would long maintain a career of prosperity. He might take a little credit to himself as being, so to speak, the inventor of the visits or trips which stood so high in favour. They gave an education out of the office which was of great value. The highest possible compliment has been paid them by other societies who had plagiarised the idea.

Mr. Williams then proposed the health of the "Council" in a few appropriate words. Mr. Porter and Mr. Church returned thanks for the Council, and proposed the "Visitors," coupled with the name of Mr. Magnus Ohren, who, in replying, said that he had known the Society of Engineers since it was a baby society, the Putney Club, in fact, and that he was intensely pleased to see it had attained such goodly proportions.

The President then proposed the health of Mr. B. Reed, the Secretary, who replied in appropriate words; and the party broke up about 9 p.m.

Visit to the South Metropolitan and Crystal Palace and District Gasworks.

For many years it has been the practice of the Members and Associates to devote three or four days during the summer months to paying visits to engineering works of interest in the metropolis or its neighbourhood. The scheme of these visits originated with Mr. Williams, the honorary secretary and treasurer; and that they are popular and useful no one can doubt. The opportunities which they give to young men of seeing practical work—of seeing something above and beyond the drawing-board and the tee-square, is of very great value; and the fact that more than one younger society have followed the example set them by the Society of Engineers affords evidence, if any were wanting, that these visits do good, and combine instruction and pleasure very conveniently.

The first excursion for the present year took place on the 29th of June, when two visits were paid, one to the South Metropolitan Gas Company's Works, the other to the works of the Crystal Palace and District Gas Company at Lower Sydenham.

The party met at noon, at the works of the South Metropolitan Gas Company in the Old Kent-Road, and were escorted over them by Mr. George Livesey, the engineer of the works,

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his brother, and Mr. Somerville. The works stand on 36 acres of ground, thirty of which are freehold, the rest being leasehold. From time to time the original works have been added to and the ground built upon, until they have assumed colossal proportions. They can now make in twenty-four hours 7,000,000 cubic feet of gas, which means that they can carbonise 700 tons of coal per day, and in winter this is actually done. The party first entered one of the comparatively old retort-houses, containing 385 double-ended retorts, or 770 mouth-pieces. Afterwards the wet condensers were visited; the gas is passed in these through large cast-iron pipes in a tank of water to cool it. The same tank is utilised in another way. Sulphate of ammonia is made from the ammoniacal liquor by a very simple process, which we shall describe presently; but to get rid of carbonic acid, and some other impurities, the liquor is heated, and to cool it again it is passed through small pipes in the upper part of the tank. On leaving the wet condensers the gas enters an air condenser, which consists of six pipes of wrought iron, each 4 feet in diameter and 20 feet long. These open at each end into a rectangular pipe, and the gas entering one of these flows slowly through the horizontal pipes and gradually deposits much of the tar which would otherwise be carried into the exhauster and cause trouble. The visitors next passed on to the old engine-house in which are two Beale's exhausters, driven by two beam engines, one at each side. The first was built by Middleton; it is a single-cylinder 20 horse-power engine, remarkable for the fact that the piston has three small rods instead of one of the proper size, so that there are three stuffing boxes to keep in order. The other engine of the same size is compound, and was built by Messrs. Easton, Amos, and Sons. Both these engines, notwithstanding their considerable age, are in good order. Steam is supplied to them by three Cornish boilers in a house close by. A visit was then paid to the purifier-house—a huge, low shed, in which stand eight purifiers, each 26 feet wide by 40 feet long, and 5 feet 6 inches deep. These will purify with oxide of iron—bog ore from Ireland—8,000,000 cubic feet in twenty-four hours; but the works are, as we have said, extending; and so another house, containing seven additional purifiers, is being put up. Each of these will be 34 feet long by 29 feet 6 inches wide, by 5 feet 6 inches deep. They will not be completed for some time. Not far from the purifiers is the modern exhauster-house, in which Beale's exhausters are driven by two 30 horse-power compound engines, by Messrs. Bryan Donkin and Co. The engines run at a slow speed, and are lightly loaded and work very well; but they have comparatively short connecting rods of, without exception, the

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ugliest and most out-of-the-way design conceivable. We understand, however, that in their newest engines the firm have abandoned this form. The gas passes from the exhausters to the Livesey gas-washer. The gas is made to bubble up in fine streams through a depth of about 3 inches of water, and then passes through successive waters until it is almost wholly deprived of its tar.

A visit was next paid to a new retort-house just completed. The whole building is carried on concrete arches, the span of each being 21 feet, with a versed sine of 3 feet. The work is 18 inches thick. The crowns of the arches, just under the furnaces, are of fire-brick. In this house are 112 doubled-ended retorts, or 224 mouth-pieces. The retorts all through the works are built of bricks specially made for this purpose, about 2½ inches thick. It is said that the cost of the bricks is just the same as that of a clay retort, the labour being additional; but the brick retort will last nearly twice as long as one of clay. We believe, however, that these brick retorts, which are of the D section, are only used by this company.

The visitors next came to the most interesting work for engineers on the premises, namely, a gasholder now in course of construction, which will be of greater capacity than any other in the world. It will suffice to give the following particulars concerning it. The dimensions of the tank are as follows: Diameter inside, 218 feet; depth in clear, 55 feet 6 inches; depth of excavation, 57 feet; thickness of walls at bottom, 5 feet, tapering to 3 feet at top; there are seventy-two rest blocks, 1 foot 6 inches high by 1 foot 6 inches wide by 7 feet long. The cone in the centre to the height of the first bench is 26 feet high, and it batters ½ inch to 1 inch, or 6 inches to 1 foot, and the other half, which is composed of sharp sand, and is 1 to 1. The wall of the tank is of concrete, composed of sharp sand, gravel, and rough clinkers, in the following proportions: Sharp sand, 2 parts; gravel, 2 parts; clinkers, 3 parts; Portland cement, 1 part; or 1 to 7, placed in position in 3 feet and 4 feet layers to the height of 22 feet from bottom; the concrete is directly against the excavation, so avoiding the necessity of backing; from 22 feet to the top of the wall it tapers, and is backed up with fine sand run in with water. The cone is covered with 1 foot of concrete, and there are twenty-four base blocks for the columns or guide ribs. The whole of the cone, bottom, and walls was rendered with two coats of cement ½ inch thick each, and closely trowelled to make the tank water-tight, without any puddle. The work has been done in about sixteen months by Messrs. Thos. Docwra and Son, of Balls Pond. The gasholder for this tank will be 214 feet diameter, in three lifts, of 54 feet each, on the non-trussed

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principle, but having a strong steel crown curb—the first time steel has been used in gasholder construction—composed of 6 inch by 1 inch angle steel rolled to an angle of 105 degrees. Attached to this angle are 12-inch by 1-inch steel plates 12 feet long, forming the first row of the side plates; and on top, to form the first row of the crown plates, is a 3 feet ring of steel, $\frac{3}{4}$ inch thick, in 12 feet lengths; attached to the underside of the plate is another angle steel 6 inches by 4 inches by $\frac{5}{8}$ inch. The whole of this curb is butt-jointed, and, with cone plates, the whole double riveted with 1-inch steel rivets. Siemens-Martin steel, of best quality, is used. The sides of each lift have forty-eight vertical stiffeners to support them when landed on the rest-blocks; and the crown-sheets, which have a rise of 14 feet in the centre, will be received, when down, upon a strong timber framing, supported by 10-inch round butts, 33 feet long, from the cone bench. The framing is composed of twenty-four guide ribs, 160 feet high, 21 inches at the bottom, tapering to 14 inches at top; the web is $\frac{1}{2}$-inch plate, having $\frac{1}{2}$-inch front and back flanges 12 inches by 16 inches wide, and roller paths of 6-inch channel iron for the two tangential and one radial rollers, each 1 foot 6 inches diameter. These ribs are braced together by twenty flat iron diagonals in each bay, they are $\frac{5}{8}$-inch thick and 8 inches wide at the bottom tiers, and $\frac{5}{8}$ inch by 4 inches at the top tiers; and between each column, or guide rib, there are five struts 32 feet apart, of a cruciform section, 18 inches by 15 inches in the centre, tapering to 15 inches by 12 inches at the ends. The gasholder will contain 5,680,000 cubic feet—working capacity—and will cost about 48,000*l*., when completed, for tank and gasholder.

It will be understood that the columns will be of wrought iron, and to avoid expense the crown will not be trussed, but will float, so to speak, on the gas. A timber scaffold will be constructed within the holder pit, and on this the crown will be built up, and this scaffoldiug will be suffered to remain to support the crown at any time when the gas may be drawn off wholly, a thing which occurs only once every five or six years or so. Much pumping has been required, and the pumping plant put down by the contractor, although temporary, is of its kind a very fine and substantial piece of work. The lift is 65 feet. No water will be allowed to accumulate in the land outside the tank until the latter is to be filled, lest the bottom should be blown up. The land water will stand within 16 feet of the surface of the water in the tank. From the South Metropolitan Gas Works the members proceeded to the Crystal Palace Gas Company's works at Lower Sydenham.

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The Crystal Palace District Gas Company was established in 1854, the main purpose of its origin being to supply gas to the Crystal Palace, although, of course, it was intended at the same time to supply the surrounding district; at that time it was but scantily populated, but the establishment of the palace gave an astonishing impetus to building operations, and attracted attention to the beauty of the surrounding neighbourhood, which has few equals near London. Under these circumstances, it is not surprising that the gas company obtained a large share in the prosperity of the neighbourhood, and to show that this has been the case it is only necessary to state that its yearly revenue has increased from 10,000*l.* in 1855 to nearly ten times that amount at present.

The original works of the company were situate on the left-hand side of the road leading from the Lower Sydenham Station, but it was long since found that the limited area of the ground available there was totally inadequate for the rapidly increasing demand of the district. A larger site was therefore obtained on the opposite of the road, upon which new works have been erected, which for extent and arrangement will well bear comparison with any metropolitan works, and ample room remains for future extensions

The present works consist of three retort-houses, one being 125 feet, and the other two each 200 feet long; these contain 48 benches of double retorts, giving a total of 672 mouth-pieces, and are equal to a daily production of four million cubic feet of gas. The other apparatus is in proportion to this production, but special care is paid to the washing, scrubbing, and purifying processes, the apparatus for which is unusually large and complete. There are three washers on the "Livesey" principle, and also three large scrubbers, each 36 feet high; there are also twelve purifiers, varying from 22 feet square to 40 feet by 22 feet, and with this extensive apparatus Mr. Gandon is able to deal very successfully with the so-called "sulphur compounds," both as to reducing their quantity considerably below the Parliamentary limits, and avoiding any nuisance from bad smells in so doing. The gas is stored in six gasholders, varying in size up to 150 feet diameter, and with a united capacity of 2½ millions cubic feet, or about equal to the present maximum daily consumption.

The district supplied by the company is extensive, covering an area of over 16 square miles, and comprising Sydenham, Forest Hill, Catford, Upper, Lower, and South Norwood, Penge, Beckenham, part of Dulwich, and part of Camberwell.

There are two or three noteworthy features about the Crystal

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Palace Gasworks, which attracted a good deal of attention. One of these is the tank for a gasholder recently erected. This stands on an awkwardly-shaped piece of ground at the very extremity of the company's land. It is a narrow slice of land, bounded on one side by a small stream, and on the other by the railway. The space available for a tank was reduced very much, and a huge concrete retaining wall had to be built, on an ogee curve, looked at in plan, to form the side of the tank. The whole tank is of concrete, and is a very clever piece of engineering, reflecting much credit on Mr. Gandon. The other noteworthy feature to which we have referred, is a new device by which the pressure in the retorts is much diminished. A species of by-pass, closed by a ball, is fitted on the dip pipes to the hydraulic main. When the ball is raised, the gas enters the upper part of the main instead of bubbling up through tar and water. The ball valve is worked by a rod and lever. The end of the lever is fitted with a hook, which is slipped under the cross bar on the mouth of the retort. When the bar is removed to draw the retort, the rod is released, the ball drops, and the retort is sealed above by the dip-pipe. Mr. Gandon has not had this at work long enough to say much with precision as to the results obtained, but there is no doubt that the yield of gas is increased.

The manufacture of sulphate of ammonia is carried on here with a very complete plant. The ammoniacal liquor is pumped up into a tank, where it is heated by a steam coil. The ammonia is driven off and passes into another chamber, where it comes in contract with dilute sulphuric acid. The liquor resulting is then passed into an evaporating pan, from which the sulphate of ammonia is subsequently dug out in coarse, broken crystals. It sells for 18*l.* to 20*l.* per ton for manure. The works throughout are kept in admirable order and high efficiency.

Visit to Messrs. Saxby and Farmer's Signal Works.

The second excursion took place on the 21st of July, when the members visited the far-famed railway signal works of Messrs. Saxby and Farmer in Canterbury Road, Kilburn. The visitors, conducted by Mr. Farmer and Mr. C. Hodgson, the general manager, visited the museum attached to the works, in which are models of all the chief inventions in signals, block, and locking, and interlocking-block signal apparatus brought out by Messrs. Saxby and Farmer, from whose works have emanated some of the most important of all the modern appliances for conducting safely the greatly devoloped traffic of modern railways. Here Mr. Farmer first explained a model of Mr. Saxby's inter-

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locking gear as invented and patented in 1856, and remarked that in principle it was the same as that of the more modern interlocking gear, though the principle has been greatly developed in application. Previous to the invention of this gear, signals and points were separately worked, and this division of the operation of two organs so necessarily co-related became so frequently productive of accidents, that their mechanical connection became absolutely necessary. It further became necessary that not only should each point be so connected to the signal belonging to it, but that all the signals at any station should be so inter-connected that no signal should give line clear while any other signal or points were in a position that would make it possible for any train to enter the line so given clear. This was done by the apparatus referred to, but the more modern development of railway traffic, and the complication of sidings and junctions, have rendered necessary the combination of the block system of working a line with the interlocking system. This was effected by an improvement patented in 1867. A further improvement was also made, which is known as the facing point lock, by means of which facing points are kept closed by a bar which is held depressed by flanges of the wheels of the vehicles of a train passing over the points. By this means the separation of a train by the movement of the points after the train has partly passed them is prevented, thus making accidents such as that at Wigan an impossibility. A further improvement, of which a model was explained to the visitors by Mr. Farmer, is an arrangement of the locking mechanism by which the related signals and points are interlocked as soon as the operator releases the catch by which the hand lever is held in position, and thus before the lever begins to move. This arrangement prevents the possibility of leaving points half open while the signals are down, and also of effecting any movement of any of the related signals and points out of the order which is alone consistent with perfect safety. A large model of a series of station and branch or siding signals was next explained to the visitors, in which all these inventions are combined, and which also illustrated the method by which collision is prevented, even when a main line driver disregards signals which may be at danger in order to cover a train from a branch about to cross or crossing his line, the main line train being in this case passed into the unoccupied branch line. This model also illustrates the method by which the gates at a level crossing are operated from the signal cabin in connection with the other signals of the line. The whole of the levers are so arranged and interlocked

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that it is impossible to move the signal levers for "line clear" until the points which they control are locked, although the levers are very numerous, and in one case two hundred and eighty levers are arranged in one signal cabin. Another, and quite new arrangement was illustrated and explained by another full size model, which shows the system of electric interlocking of the points and block signals. This is the invention of Mr. C. Hodgson, and the arrangement is such that by moving the small handle of the electric block signalling communications between two stations, a catch is held or liberated which controls the locking gear of the levers relating to the line, respecting which the electric signal for line clear or train on road has been telegraphed from the next station. Thus the block system is so connected with the interlocking system that a train cannot proceed on a line signalled clear until the points and signals of the next station are right in their mechanical interconnection. This system has been some time in operation at Waddon on the Brighton line, and is being fitted on the Tunbridge and Eastbourne line, soon to be opened. It is also in use, or in course of erection, at forty stations on the Antwerp and Brussels lines. Yet another means of protecting the lives of railway travellers was illustrated by a full size model of an arrangement by which the signalman at one station is enabled to put the signals of a distant station at danger in spite of the signalman at the distant station, who may have communicated his intention to start a train. Thus the signalman at one station has the most perfect control on the two portions of line to and from him by simple breaking the electric current which operates block-interlocking signals without interrupting the electric communication respecting signals and trains.

After the models in the museum had all been inspected and explained, the visitors inspected the various departments of the works, where they saw in different stages the manufacture of the parts of all kinds of railway signal and controlling apparatus, and the assemblage of these in the completing departments, including the construction of signal cabins and all the various paraphernalia connected therewith. The works are fully employed, and to a great extent on foreign orders.

Visit to South-Western Railway Works at Nine Elms.

The third excursion took place on the 18th of August, when the South-Western Railway works at Nine Elms were visited by permission of the company. The members were received by

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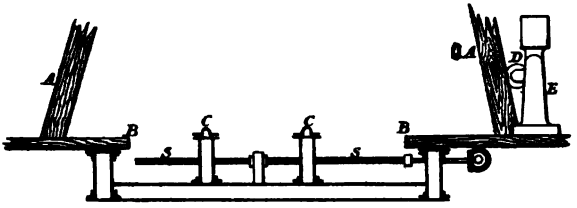
Mr. W. Adams, M.I.C.E., locomotive superintendent, and conducted over the different departments of the works by him and his chief assistant, Mr. Garrett. The upstair carriage, painting, and finishing departments were first visited, and here the visitors inspected the crane for lifting the carriages from the rails on the ground to the finishing shops. In the floor is an opening between a pair of the girders that support the floor, sufficiently wide and long to admit a carriage body. Between two of the girders are two cross girders, upon which rest two longitudinal girders C C. These are arranged to slide from the position shown,



where they are 4 feet 8½ inches apart to the edges B B of the opening. This is accomplished by two pairs of right and left-handed screws S S driven by gearing from the engine at E, which also acts as the hoisting engine by hauling on a chain running under a pulley at D, and over another at the top of the two pairs of fixed shear legs A A. When a carriage is to be lifted the screws S S are set to work, the girders are slid over to B B, the carriage lifted by slinging from two bars placed under them, and when above the level of the floor the girders C C are returned to their places and the carriage rested upon them. Hitherto only the bodies of the carriages have been lifted in this way, but Mr. Adams is strengthening the lift so as to lift the carriages complete with under frames and wheels. By this means he will save the yard room usually occupied by about sixty under frames under repair. All the shops referred to are large and light, and an extensive arrangement of water pipes is fixed under all the roofs, so that in case of fire water may at once be turned on in one or any department in which it issues from a number of perforated pipes. Passing from these shops the visitors were conducted to the locomotive repairing shops, where they saw a number of engines new and old in different stages of construction, dismantlement or repair. It was noticeable that Mr. Adams has removed and is removing

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the doubled chambered fire-boxes, and replacing them as opportunity occurs with plain boxes. It is said that the steaming power of these boxes is best shown by the fact that when driver A. is checked upon the quantity of fuel consumed in his engine as compared with the consumption of another driver B., he answered, "Yes, but B. has a plain box." Thus not only is the coal consumption even less, but the large plain fire-boxes of modern practice remove the great difficulties and cost attending the repair of the double boxes. No steel is being used either for fire-boxes or boilers, and iron tubes chiefly from the works of Piedbœuff, of Dusseldorf. They are tapered at one end by reduction and at the other by enlargement, so that they drive into the tube plates and fit, but are afterwards swelled and riveted over. The visitors were also conducted over the wood-working department, and here those who were acquainted with it a very few years ago were much surprised to see the great changes that had taken place, and to see the operation of the wood-working machinery which has been introduced by Mr. Adams. Several of these machines are of American patterns, or built upon American notions, even when not of American make. One large rack-bench was shown in action, cutting 12 inch-balks at the rate of 90 feet to 100 feet per minute, or 5 inches per revolution of the saw. This machine was made by the Lane Manufacturing Company, of Montpellier, U.S., under Lane's patent. On one boring machine, by Messrs. A. Ransom and Co., a large router tool was in use in making the large mortices in the wood framework. A very ingenious hand-saw tooth-setting machine, by Messrs. Fay and Co., was also seen at work. Several of the machines, including a morticing machine with continuous feed and small saw bench for pattern and fine work, arranged with two saws, either of which may be employed at will, were supplied by Messrs. Richards and Co., London. Passing into the foundry, a well filled and occupied shop, the visitors saw some moulding machines, by Butterfield, of Keighley, employed in making axle-boxes. Great alterations are being made in the drainage and arrangement of sidings and shedding, &c., at Nine Elms, and the works are of a character which must tend to the great reduction of cost of new work and repairs, though this may not at the first be evident.

Visit to Chatham Dockyard.

The fourth and last excursion for the year was made on the 21st of September, when the Members and Associates visited

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Chatham Dockyard, and the extension works there in progress. The visitors were received and escorted over the works by Mr. Edwin A. Bernays, superintending engineer, and Mr. Newton, executive engineer in charge of works.

What is known as St. Mary's Island is a waste piece of land lying seaward of the old Chatham Dockyard. For very many years proposals have been made from time to time to utilise this piece of land. The final details of a scheme were settled in all their principal features by Colonel, now Sir Andrew Clarke, in 1864. The work consists of a string of three basins extending right across the island. The first basin opens out of Upnor Reach, and is called the repairing basin. It has a mean length of 1270 feet, a width of 700 feet, and an area of about 21 acres, and is mainly used for the reception of newly launched ships, or of those stripped for repair after return from commission. At the eastern end of this basin is a passage opening into a, second or factory basin, which is used for the reception of vessels while their engines and machinery are being fitted and placed on board, or are in course of removal. This basin has a mean length of 1245 feet, and a width of 700 feet, with an area of 20 acres. This basin will open into the third or fitting-out basin, which is at present in course of construction. It is of irregular shape, and will have an area of about 27 acres. Its breadth is the same as that of the other basins, viz., 700 feet, and this dimension was fixed with regard to the advantageous working of the basins, the usefulness of a basin depending upon its available wharf accommodation rather than upon its mere superficial area. Out of the basin farthest from Upnor Reach open four docks, each 500 feet long. Three of these are large enough to accommodate any ship in the navy save the *Inflexible*, and the fourth is large enough to take her in. The basins are all divided by locks, which are closed by caissons of wrought iron. These caissons are being constructed by Messrs. Westwood, Bailey, and Co. They slide horizontally in and out of their places, being withdrawn into suitable cells at the sides. They work at an angle of 1 in 40, and will be actuated by steam power. We may say here that throughout the whole of the extension works steam, and not hydraulic power, will be used to work the caissons, drive winches and capstans, and operate the great shears, which will lift 100 tons. The Admiralty preference for steam is based principally on the fact that the machinery occupies much less space than hydraulic gear, and that it is unaffected by frost.

The first step to be taken in commencing the works, consisted

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in excluding the river Medway, which is tidal at Chatham, and far above it. It quickly became apparent that no ordinary system of construction would give a suitable dam. The river's bottom consists of mud, varying in depth, but reaching in places some 28 feet. This mud rested on chalk, silt, and gravel, in various places. Mr. Bernays decided that, all things considered, the best and cheapest way of making the dam would consist in tipping soil, excavated from a suitable locality not far distant, into the river; and this plan was carried out. Tipping took place from both ends, a railway being of course made for the purpose. The whole length of the dam is 1200 feet. When the ends of the dam had approached within 170 feet of each other, it was found that no further progress was made, the material tipped—principally a kind of chalky loam—being washed away as fast as it was deposited. The depth and width of the gap were carefully measured, and it was found that an opening 170 feet wide, and about 18 feet deep below high water mark, sufficed to provide for the influx and efflux of the water. This point being settled, a gap of the stated dimensions was cut in the enbankment, near one end, to act as a safety valve, and the original gap or space not closed was then tipped into and made good without any trouble. The artificial gap had now to be closed; but in dealing with this Mr. Bernays had to fill up a depth of only 18 feet, instead of working up through the mud from the bottom of the river. Watching his opportunity, he had every available waggon on the works filled, and a little before dead low water of a neap tide he began filling as fast as possible into the artificial gap. As the tide began to rise the combat between the engineer and the water became extremely exciting. The water was fought literally inch by inch, but Mr. Bernays won, and the gap was closed in one tide, and before the next the work was strengthened and consolidated. This was really a masterpiece of engineering, distinguished by great boldness and originality, and carried out with complete suecess. The whole dam is quite water-tight, the mud of the river in which it is sunk puddling it without artificial aid. A few inches of clay facing are, however, provided in some places to check the eroding action of the little waves in easterly winds.

Turning now to the docks and basins themselves, the most noteworthy feature, apart from their great size, is that they are built wholly of concrete, with certain granite facings. The dock floors, too, are of brick. The concrete work is very much superior to anything of the kind we have seen elsewhere. It is composed of one of Portland cement to twelve of such gravel as

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can be dredged in the neighbourhood, and which is delivered at the works for 6d. a yard. This gravel contains a good deal of loam, but this does not appear to do any harm. The whole of the work is faced with a superior concrete 9 inches thick, save in certain "noses" and projections, where it is as much as 2 feet thick. The facing concrete consists of four of puddling and mill furnace slag from the scrap iron forge in the dockyard, two of clean sand, and one of cement. The slag is crushed small in a Blake's stone breaker, and this facing is carefully worked down between the mould boards and the coarser concrete. The result is admirable, and it is a noteworthy fact that all the operations are carried out by convict labour, with the exception of a small percentage of highly skilled men, who direct operations and themselves do the most difficult portions of the work. Mr. Bernays speaks highly of convict labour; although slow, he says that their work is very good and sound; there is no scamping, and the different gangs vie with each other in giving finish to their productions, while some of them manifest great ingenuity in devising labour-saving appliances. The excavations lie far below the bed of the river, and the walls rise from this depth considerably above it. In many places there is already a depth of 70 feet or 80 feet of concrete, and when the works are finished they will be practically monolithic. St. Mary's Island will have been petrified round the docks and basins. From the extension works the members proceeded to the dockyard, where Admiral Brandreth, Admiral Superintendent, had given instructions that the visitors were to be shown typical ships, and this object was kept in view. The first ship visited was the *Nelson*, a sister of the *Northampton*. The *Nelson* was built and engined by Messrs. John Elder and Co. She is 280 feet long between perpendiculars, 60 feet wide, and draws 24 feet. She has three principal decks, and carries four 18-ton guns, and eight 12-ton guns on the main deck. This ship cannot be better described than in the words of Mr. King*:—"The framing is on the usual longitudinal system adopted in the construction of British ships of war, and in this instance the longitudinal frames are made of steel, so as to combine lightness with strength. The double bottom extends for about 150 feet amidships, and the space between the inner and outer skins is divided into many water-tight compartments. Accordnig to the system recently adopted for armoured ships, there is a central longitudinal bulkhead, besides numerous transverse

* 'The War Ships of Europe.' By Chief-Engineer King, U.S.N.

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bulkheads underneath the lower deck and wing-passage bulkhead. Altogether, including the spaces between the two skins, there are ninety water-tight compartments; all the doors leading to these compartments are fitted water-tight and worked by machinery, and every conceivable precaution has been taken to provide against destruction by rams and torpedoes. There are three principal decks: The lower, main, and upper. The protecting armour consists of a belt at the water-line of about 181 feet in length amidships; this belt benig 9 feet deep, 4 feet above water and 5 feet under water. It is put on in two strakes; the upper strake being 9 inches thick upon a 10-inch backing of teak, and the lower one 6 inches thick upon a teak backing of 13 inches. Extending across the ship at each end of this armour-belt there is an armoured bulkhead, which extends from the bottom of the armour-belt, 5 feet under water, to the upper deck, and has in all a depth of 22 feet. Its thickness is 9 inches above water, tapering to 6 inches at the bottom. Between the main and upper deck these bulkheads are shaped so as to form corner ports at the fore and after ends of the battery. Between the armour bulkheads, and at the upper level of the armour-belt, the lower deck is formed throughout of 2-inch plates, so as to protect the machinery, boilers, magazines, &c. The horizontal armour is a peculiar feature of these ships. For about 57 feet at the fore end there is an armoured deck. This deck is 2 inches thick, and 5 feet under water at the junction with the armoured bulkhead, but inclines deeper towards the stem, and terminates forward in the ram. There is likewise a horizontal armoured deck of the same thickness and same depth under water, extending from the after armoured bulkhead to the stern. These submerged armoured decks are intended to protect the lower part of the ship before and abaft the armoured bulkheads, and especially the steering gear provided for emergencies. From the above outline it will be seen that the central part of the vessel for 181 feet in length, in which all the propelling machinery is contained, may be regarded as completely protected from ordinary shots of the enemy. The ends of the vessel above the submerged decks are entirely unprotected by armour, and may, it is supposed, be riddled with shot without serious injury to the flotation of the vessel. The armament will consist of four 18-ton guns and eight 12-ton guns on the main deck, and six small guns on the upper or spar deck; the latter being intended for use as torpedo-boat destroyers. Two of the 18-ton guns, one on either side forward and one on either side aft, are

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situated behind the oblique portion of the armoured bulkheads, and the ports are so cut that these guns can command a cross fire at the bow and stern. The eight 12-ton guns disposed equally on either side are termed intermediate, and have in front of them the thin sides of the ship only. They are separated by a transverse bulkhead or splinter-screen 1 inch thick, intended to cut off each gun's crew from the others. This broadside of guns is designed to be loaded and laid in close engagement under the shelter of the bow or stern armour, and may be fired by electricity without exposing the crew. The ram is a heavy plate, triangular in shape, set vertically, and terminating in a sharp point about 11 feet in advance of the stem; it is supported by two side plates 3 inches thick, which may be regarded as a continuation of the armoured deck. The rudder, which is massive, is 18 feet deep by 11 feet in breadth, and is formed by two thicknesses of teak planking set in a strong iron frame. The vessel has bilge keels 33 inches deep, formed of two plates riveted together, and extending in length amidships for about 100 feet. The outer bottom of the hull below the water-line is sheathed with a 3-inch thickness of teak, which is covered with zinc. The seams between the strakes of sheathing are left uncaulked. There are to be three masts fitted, as for a fullrigged ship, and the coal-bunker accommodation is sufficient for a long voyage and cruising in distant seas. In time of war it is intended that only the lower masts shall stand. The novelty of design embodied in the *Nelson* and *Northampton* consists in the system of armouring. As may be readily seen, the object aimed at has been to give thicker plates to vessels of this class over the vital parts, at the expense of the exposed parts, and so to increase the offensive power by carrying a heavier weight of ordnance. The machinery of the *Nelson* was designed and constructed under the direction of Mr. Kirk, the manager of the engineering works of Messrs. Elder and Co. She is fitted with twin screws, each to be driven by an independent pair of compound engines, with vertical inverted cylinders, of the collective power of 3000 horses; giving an aggregate power of 6000 indicated horse-power for both pairs of engines. The diameter of the high-pressure cylinder is 60 inches, and the diameter of the low-pressure cylinder is 104 inches. The length of the stroke is 3 feet 6 inches, and the number of revolutions to be obtained on the trial seventy-five per minute. These engines are constructed entirely of wrought iron, steel, and brass, except the cylinders, cylinder covers, steam and expansion valves. The

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two pairs of engines are tied together by wrought iron braces, and are fixed in the ship directly opposite each other. The central longitudinal bulkhead divides the two pairs of engines, and all the pipes are arranged so that, in the event of collision or other casualty to the bottom of the vessel, either pair can be worked separately. The crank shafts are in two parts, interchangeable, 16½ inches in diameter in the bearings, with an aggregate length of bearing of 9 feet 6 inches. The propeller shafts are hollow, and are made of Whitworth's compressed steel. The screw propellers are to be 18 feet in diameter, to work outwards, and of the Mangin type, i.e., two two-bladed screws on each boss, separated from each other. The boilers are ten in number, with three furnaces in each, and are set back to back against the longitudinal bulkhead, with the fronts towards the sides of the ship. They are oval in shape, 12 feet 6 inches wide by 14 feet 6 inches high, and 9 feet 6 inches long; and are divided by transverse water-tight bulkheads into four separate fire or boiler-rooms. The furnaces are made in short lengths, riveted together with flanges having distant pieces between them. The pressure of steam is to be 60 lb. per square inch. All the necessary pumps and equipments described for other vessels are here provided."

A visit was then paid to the *Agamemnon*. The length of this ship between perpendiculars is 280 feet; breadth, 66 feet; displacement, 8492 tons; and tonnage, 5469. Her engines are of 6000 horse-power indicated, and her armament consists of four 38-ton guns, carried in two turrets, which will be protected by compound armour-plates from Messrs. Cammell and Co.'s works at Sheffield. From the *Agamemnon* the visitors proceeded to the *Orion*, which has a central battery, and is armed with four 25-ton guns. Her engines are of 3900 horse-power indicated. The next vessel inspected was the *Superb*, formerly the *Aamidiyeh*, which, with the *Orion*, at first called the *Bourdji Zaffer*, was originally constructed to the order of the Turkish Government, and afterwards purchased by our own. The *Superb* carries sixteen 18-ton guns, twelve being placed in her battery, two forward, and two aft. She will also carry twelve Whitehead torpedoes, which will be discharged from four carriers, two forward and two aft, at a height of 4 feet above water level. Her engines are of 7340 horse-power indicated.

After these ships had been inspected, the visitors were conveyed on the narrow gauge—18-inch—railway which runs through the yard to the shed wherein the *Polyphemus* is being

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built. This vessel is one of the most remarkable ever constructed.

She will not be fitted with masts or sails, but will carry a pole for signal purposes. The principal dimensions, &c., are as follows:—

Length between perpendiculars	240 feet.
Breadth, extreme	40 feet.
Depth of hold	18 feet 9 inches.
Immersed mid-ship section	625 square feet.
Mean load-draught of water	19 feet 9 inches.
Displacement, load	2610 tons.
Builders of machinery, Messrs. Humphrys, Tennant, and Co.	
Type of engine, compound, horizontal, single piston rod.	
Number of cylinders	4.
Diameter of high-pressure cylinders	38 inches.
Diameter of low-pressure cylinders	64 inches.
Stroke of pistons	39 inches.
Number of screw propellors	2.
Total weight of machinery, including water in boilers and 10 tons of spare gear	490 tons.
Indicated horse-power, maximum	5500.
Speed of vessel, estimated, maximum	17 knots.

The engines are designed for simplicity and saving of weight. The inboard propeller shafts are hollow, of Whitworth's compressed-when-fluid steel. The surface condensers are brass. There are no expansion valves. Many parts of the engine are made of steel. The boilers are of the locomotive type, ten in number, manufactured of Landore steel, and designed to carry 120 lb. pressure on the square inch. The boilers stand athwartships, and are divided into two groups of three and two respectively, with a fore-and-aft bulkhead between them, thus making four fire-rooms in water-tight compartments. The uptakes all lead into one chimney, which is fixed. The engines each occupy the full breadth of the ship. The port engines are aft, the starboard engines forward. She is built throughout of steel, and somewhat resembles Winan's celebrated cigar ship, a full description of which noteworthy craft appeared in *The Engineer* many years ago. The *Polyphemus* will carry no guns, save one or two small pieces on deck; but she will be able to launch torpedo after torpedo from the orifice—which resembles the mouth of some fishes—in the cut water, and about 8 feet below the water level. But besides this she can discharge other torpedoes at each side. She will be fitted with a ram bow or snout of formidable dimensions. She is divided

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into a great many compartments by suitable bulkheads, and in her hollow keel, if we may so call it, she will carry blocks of cast iron each weighing 20 tons. Should she take in much water from being pierced by an enemy's shot, these blocks can be dropped into the sea at a moment's notice, and the ship so far lightened. Her turtle back will be covered with scale armour secured to 2-inch plates. This scale armour consists of a series of tiles, each 10½ inches by 10 inches, by ⅛-inch thick, made of Whitworth compressed steel. The tiles are secured, with one screw stud at each corner, and one in the middle, the whole surface being flush; and it is anticipated that she will be impregnable to any gun which another ship of war could bring to bear upon her.

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October 4th, 1880.

JOSEPH BERNAYS, PRESIDENT, IN THE CHAIR.

MODERN STEEL AS A STRUCTURAL MATERIAL.

By W. WORBY BEAUMONT, Assoc. M.I.C.E.

The object of this paper is not to bring forward any new experiments on the properties of steel as employed in constructive work, but to invite discussion upon a few points which may occur to the engineer to whom it seems desirable to consider the relative advantages of mild steels and iron in some mechanical or constructive work. For several years the substitution of steel for iron in various structural work has occupied the attention of engineers and metallurgists, but the progress which has been made, compared with the hopes that were entertained when steel made by the Bessemer process became cheap enough to make its cost, strength for strength, comparable with that of iron, has not been great. There are classes of structures in which a reduction in weight would be a material advantage, even when attended with an increased total cost. Ships, boilers, and girders, may be instanced as examples. In this direction, therefore, engineers turned their attention, with a view to the application of steel. The difficulties, however, which attended the manipulation and connection of steel in structures largely composed of plates checked its application. Many failures attended the attempts to use it, chiefly resulting from apparently anomalous behaviour of the metal under what were considered similar conditions, but more, perhaps, owing to the special treatment which it required as compared with iron. Those who had been long accustomed to the manipulation of iron were unable to depart from past practice sufficiently to operate upon the new material with all the careful attention to its different properties which these demanded. Thus, although the difference in its behaviour in the hands of the smith and plate worker, as compared with iron, was considered in several of the details of manipulation, certain other

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peculiarities were lost sight of in the assemblage of parts, which resulted in the destruction of work when almost completed. Even twenty years ago, before the modern cheap steels had been offered, steel made by the crucible process had been successfully employed on a small scale for boiler work. Very careful attention to the behaviour of steel under treatment had no doubt been observed, as it might easily be on a small scale; but when, some years after, attempts were made to use Bessemer steel for boiler and bridge work, difficulties arose, some of which were attributed to the nature of the material and some to the want of thorough care on the part of the workmen. Even when plates of this material cost more than iron for boiler construction, and very much more than iron for bridge and girder work, attempts were made to use it for the latter on account of the several advantages which would arise from a decrease in the permanent load of bridge structures. Failures, however, of parts of these structures both before and after completion, due to the want of the observance of the special treatment which the material demanded, discouraged its employment. The endeavours of steel makers during the past few years have, therefore, been directed to the production of steel possessing properties so far similar to wrought iron that no great departure from the methods of working this material need be made. Apart from the frequent want of uniformity in the mechanical properties of the Bessemer steel plates of a few years ago, it generally exhibited an absence of toughness, which not only made it difficult of manipulation in the hands of the plate-smith, but caused its destruction after being built into a structure. Its uncompromising rigidity rendered it incapable of accommodating itself to, and gradually eliminating from itself, the residual strains originating in unequal heating and cooling, and also to the unequal strains visited upon it by other parts of a structure of which it was made to form a part, either by riveting or other modes of connection. It was not that the steel did not appear to possess the qualities when tested in the testing machine, but its behaviour was apparently different when employed in full size pieces or plates from that exhibited when tested in small pieces in the machine. This difference indicated that there were differential internal molecular strains resident in the whole plate, which were eliminated when the same plate was cut into strips. This elimination, it was considered, could not take place in the whole plate on account of the harshness of its material. Annealing was resorted to, but only with partial success, the complex nature of the strains in a plate of the material, even when cooled slowly, being sufficient, when

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aggravated by extraneous strains, to cause its rupture. It is perhaps not necessary here to consider the nature of the strains in a plate of iron or steel resulting merely from slightly differential contraction in cooling, but it may be observed that though small, these strains may have a material influence on the strength of a plate as a whole, and that they would be greater in the thicker plates. This may be referred to hereafter.

The necessity of imparting to steel plates the toughness characteristic of good wrought iron has thus induced steel manufacturers to devote their attention to the production of steel possessing great ductility. It is on this point that much might be said, because in the search for toughness the advantages which the employment of steel in some structures seemed at one time to promise are being almost lost sight of. Not only are these advantages likely to be lost, but the great ductility being imparted to soft steels and ingot iron in search for this necessary toughness, seems likely to give us a material inferior in some essential qualities to much of the wrought iron hitherto in use. Toughness in plates has not been obtained, but instead thereof great ductility attended with low elastic strength.

It may be premised that the structural value of a metal will be proportionate to the degree in which it combines high ultimate strength with high elastic limit and wide range of elastic and ductile extension, or in proportion to the relation in which it combines toughness with strength. Thus a metal which possesses high ultimate strength and high elastic limit with small ranges of extension, will not have great structural value, as it will not be capable of withstanding impact strains. Again, a metal possessing high ultimate strength with low elastic limit will have small value for structural purposes, as, though high ultimate strength is an essential property, the limit of elasticity determines in almost all cases the sectional area, and, therefore, weight of metal required for a given duty. A high elastic limit, with considerable elastic extension, must be obtained, combined with great toughness beyond that limit, or, in other words, a high elastic limit must be attended by a considerable range of extension both within and beyond that limit, combined with high ultimate strength.

The tendency, however, in the production of the modern mild steels and ingot irons which will eventually no doubt supplant wrought iron made by the puddling process, is to make a metal which is far from combining these properties in such relations that it is best suited for structural purposes, or so

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as to offer those advantages which were at one time supposed to be attainable by the use of steel.

The best index to the comparative structural value of different materials is probably that obtained by the application of Poncelet's formulæ as simplified and made applicable for practical purposes by Robert Mallet. This formulæ expresses by coefficients Te and Tr and Te^1 and Tr^1 the work done by an extending or compressing force upon an elastic prismatic body, at the point where its elasticity becomes permanently impaired, and its form distorted, and at the further point where rupture occurs, or, in other words, it expresses the balance in any material between strength and toughness, and was designed to give a more exact index to the structural value of materials than was given by the early experimenters down to the days of Telford, when the force necessary to produce rupture was alone considered. The formulæ are probably known to most of the members of the Society, having been given by Mallet in a paper "On the Coefficients of Elasticity and of Rupture in Wrought Iron," published in Vol. XVIII. of the 'Proceedings' of the Institution of Civil Engineers, and subsequently employed by Dr. Pole in his book on 'Iron as a Material of Construction,' but they may be repeated here.

Let L = the length of the prism;
l = the unit of length;
A = the transverse sectional area of the prism;
i = the extension, or compression which is proportionate to $\frac{l}{L}$;
P = the force of extension or compression which is proportionate to A; and
e = the elastic resistance which balances P, or the modulus of elasticity.

The force P is, of course, variable between o and i,

$$i = \frac{P\,L}{e\,A} \text{ and } P = \frac{e\,A}{L}\,i.$$

If x be any small extension, or compression less than the nth part of i, P corresponding to $x = \frac{e\,A}{L}\,x$. The work done in extending, or compressing through the infinitely small additional range $\Delta^1 x$ (assumed uniformity) $= \frac{e\,A}{L}\,x\,\Delta^1 x$, and the whole

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work done when i = the compression or extension at which the elasticity of the material is permanently changed, or the elastic limit reached, is

$$Te = \frac{e\,A}{L} \int_0^i x\ \Delta^1 x = \frac{1}{2}\frac{e\,A}{L} i^2,$$

$$\text{or } Te = \tfrac{1}{2}\, e\, i^2, \text{ or simply } = \tfrac{1}{2}\, P i;$$

for the unit of length and section. The value of the coefficient Tr is arrived at in the same way, by substituting the corresponding values for P and i due to the moment of crushing or of rupture. Thus for a material having under tensile strain an elastic limit P of 12 tons per square inch, and elastic extension e of 0·02 inch in a foot of length, and having an ultimate strength of 22 tons per square inch and a total extension of, say, 1 inch, the

$$\text{coefficient } Te = \frac{P \times 2240 \times \frac{e}{12}}{2},$$

or

$$Te = \frac{12 \times 2240 \times \frac{0\cdot02}{12}}{2} = 22\cdot31,$$

and

$$Tr = \frac{22 \times 2240 \times \frac{1\cdot0}{12}}{2} = 2052\cdot50;$$

while with another material having an elastic limit of, say, 14·22 tons, elastic extension 0·024 inch; ultimate strength, say 23 tons, and total extension of 1·6 inch in a foot the coefficient Te = 31·8 and Tr 3501.

In order to determine the relative structural values of several materials, it is thus necessary to take Te and Tr simultaneously into consideration, though Te is the coefficient of the greater importance in most structural work.

About a dozen years ago Bessemer metal was offered for bridge and ship construction which in the testing machine showed an ultimate tensile strength of from 34 to 40 tons per square inch, an elastic limit from 20 to 23 tons, and a range of ductile extension of from 10 to 18 per cent., while the tests of plates considered suitable for the shells or barrels of boilers showed figures not much lower than these. The failures which occasionally attended the application of this steel, however, discouraged the extension of its application by engineers, who hoped that greater uniformity in the mechanical properties of

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the metal would gradually be obtained by the steel-makers. A steel of somewhat lower tenacity and greater ductility, attended by greater uniformity in composition and behaviour, was then produced, and this indicated that steel-makers and engineers must look to steel of milder character for the removal of the difficulties which had attended the structural application of cheap steels, that is steels not produced by the crucible. The result of this was that engineers specifying steel for, say, bridge work, stipulated that it should not possess more than a certain maximum tenacity, a reversal of the stipulation that had always and does obtain with respect to iron. As a further result of this, and to ensure that the harder steels of comparatively high tenacity, but less uncertain character, should not be used in the construction of bridges, the Board of Trade regulations upon the subject limited the tensile strain on any part of a structure to 7 tons per square inch. This has led to the endeavour on the part of all steel-makers to produce the very mild, soft steels now largely used, some of which affords the engineer no help towards producing the lighter structures which a dozen years ago it was promised that steel would give them. Boiler shells must be made nearly or quite as thick as if they were constructed of iron.

As an instance in illustration, reference may be made to the results of a series of experiments made on iron and mild steel, in order to determine their respective values for high-pressure boiler construction, and described by Mr. David Greig and Mr. Max Eyth in a paper read before the Institution of Mechanical Engineers, in June 1879. Amongst other experiments, the mechaninal properties of mild steel and Yorkshire plates under tensile strain were determined. The plates—both iron and steel —were obtained from Messrs. John Brown and Co. and Messrs. Cammell and Co. In the paper referred to, the mean tensile strength, elastic limit, and extension are given as follows:—

	Ultimate strength. Tons per square inch.	Elastic limit. Tons per square inch.	Extension. Per cent.
Iron plates	22·27	16·06	36·2
Steel plates	25·80	16·74	28·3

The extension given is in a length of 6 inches. If all reference to the secondary elastic limit, which may be induced by repeated application of strain up to and slightly exceeding the elastic limit of each preceding test, be omitted, it will be seen that the so-called steels, to which the above figures relate, present scarcely any structural advantage over iron. The elastic limit is nearly the same, and though its ultimate strength is greater

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than that of the iron, its ductility, as shown by its range of extension, renders its greater ultimate strength of little value, for very long before it can be strained to that limit in any structure, it stretches so much that the accumulation of strain is prevented, and this may be shown to take place in bridge as well as boiler structures. With respect to the latter, Messrs. Greig and Max Eyth observe that "the tensile and shearing strength of the material supplied for these tests by some of the most experinced makers of steel, and by them, no doubt, considered the best for the purpose, has in the experiments proved to be not more than 10 per cent. above that of the iron supplied at the same time, and its want of hardness, as distinct from tensile strength, has proved to be a very serious disadvantage in boiler work. What the trade now requires is a return to a harder material of increased tensile strength without losing the homogeneity which is at present obtained at the expense of hardness." Again, in speaking of the results of the test, under hydraulic pressure, of the complete boilers made of this steel, they say "the compression of the rivet and elongation of the rivet hole resulted invariably in leakage, which prevented the necessary pressure from being obtained. Each rivet became its own safety valve, and the strain put on the weakest part never reached more than 70 per cent. of the breaking strain. This is the point where additional hardness of the material would be most useful, as it would prevent the opening of the rivet holes, which now makes a boiler useless long before the breaking strain is reached." This evidence is, therefore, to the effect that no structural advantage is obtained by the use of these steels in place of iron.

If we turn now to the results of tests, made by Mr. Kirkaldy, of Siemens' mild steel, we find that the mean results for plates of from 0·37 to 0·70 in thickness, annealed and unannealed, are as follows:—

	Ultimate strength. Tons per square inch.	Elastic limit. Tons per square inch.	Extension. Per cent.
Unannealed	31·02	14·50	23·4
Annealed	28·84	12·84	24·6

From these figures it will be seen that though this material (like that used at Messrs. Fowler's works), may be very safe, it presents little structural advantage over iron-plates, the limit of elasticity being low, permanent set taking place at as low as 12·84 tons per square inch when the plates are annealed. It is, however, observable that though the extension of this metal reaches a total of 24·6 per cent., it is less than 11 per cent.

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annealed, and under 7 per cent. unannealed at a strain of 26·78 tons, thus indicating very considerable toughness and probably greater value as a structural material than that tested by Messrs. Greig and Max Eyth.

Material described still more recently gives the engineer even less of hope that the modern steels for structural purposes will enable him to produce lighter structures than he can do with iron. It would even appear that greater hope of obtaining a material of high structural value is to be found in iron, for it was recently stated at a meeting of the Iron and Steel Institute by a member, that he had been experimenting with puddled iron, the elastic limit of which ranged from 19 tons to 20 tons, while its ultimate strength was 29 tons and its elongation between these strains was 23 per cent. in a length of 8 inches. The elongation within the elastic limit was not mentioned. Unless a higher elastic limit can be obtained, no advantage in a structural sense is secured. High ultimate strength is a comparatively useless quality if the elastic limit is low, and great range of extension is also of no service. In bridge work, a very high range of extension is useless, because the members under tension would elongate if strained beyond the elastic limit, to a greater extent than the members under compression would compress, and thus the structure would fail by the destruction of the balance in the disposition of the strains on the different parts. Even if the material showed a range of compression equal to its range of extension this would remain equally true, because in order to secure the necessary resistance to bending or buckling, members under compression must be of greater sectional area than is indicated by the static strain. Thus a higher elastic limit is the first essential in steel for structural purposes. This it appears can only be obtained by making the steel harder, which, by the Bessemer process at least, if not by other largely used processes, it seems cannot be secured without other attendant qualities or properties which make the material difficult to work, and more or less uncertain in its behaviour under mechanical treatment. Whether this is really now so, or must continue so, it remains for the steel-makers to show; but it does at least seem plain, that even with some of the so-called mild steels a little misgiving is pardonable on the part of the boiler-maker, who wonders what he may find in a boiler shop to-morrow where he has left a nearly or quite finished boiler to-night. Not only, moreover, is this mild steel way of getting over the difficulties attending the use of the strong steels, likely to rob engineers of much that the latter material promised, but by the still existing custom of denominating what is really iron by the term steel, we are likely

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to lose the advantages gained by using the harder steels where that has been possible, for already a good deal of so-called steel, in which there is not much more carbon than there is in a Lowmoor bar, is being worked up into steel rails and steel tires. It is true that rails of very hard steel do not wear quite so well as those of a tougher quality, but it remains to be seen whether some of the very mild metal being rolled into rails to-day may not soon acquire battered heads under the heavy traffic of modern locomotives. Such rails will not laminate, but it remains to be seen whether splitting will not result from the deformation by battering.

It will have been observed that in this short paper the attention of the writer has been almost wholly confined to references to plates. This has been done because it is chiefly in plates that improvement has to be looked for from the steel-maker. With bar steel, the difficulties in manipulation and connection in structures have not been so great as with plates, and failures, whether due to imposed or internal differential molecular strains have not been so frequent; sections are less in area and forms less capable of initiating and transmitting destructive strains. Consequently mild bar steel need not be so ductile as mild plate steel, and hence the structural value of mild bar steel is much higher than that of plates, and engineers can use it to advantage. In the course of a very interesting lecture delivered by Dr. Siemens at the Royal United Service Institution in March 1879, he gave a table showing the results of a series of tests of mild and hard steel bars up to, and slightly beyond their elastic limit. This table is of great value as affording evidence of the structural value of these bars, and it is to be greatly desired that similar observations should be made on all kinds of modern metallic structural materials. The mild bars to which Dr. Siemens' table refers show a mean elastic limit of 17·37 tons when annealed, though the same bars showed the lower mean elastic limit of 16·62 before being annealed, and curiously the elastic extension is also greater in the annealed bars, the mean extension in bars 5 feet and 4 feet 11 inches in length, being 0·088 inches and 0·086 inches, the value of Te of the bars being by the before-mentioned formulæ respectively 57·04 and 53·348. This denotes a high structural value, although this indication must be taken with the value of Tr, which cannot be gained from the table referred to. Such material, however, is not to be had, or cannot be safely used in plates, and even in bars has been very little used in bridge work. Steel-makers have yet to satisfy engineers that it can be safely used.

The most of the recorded experimental results of tests of mild

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steels do not give the extension at the elastic limit, so that comparisons with other materials cannot at present be made. From what has been said, however, it will have been seen that it is very necessary that these figures should be obtained, and what has often been observed may be here repeated, namely, that in order to secure the production of a satisfactory series of tables of the mechanical properties of different structural metals, experiments should be conducted on a uniform basis and with uniform lengths of test pieces, or if not of uniform length, they should be of a minimum length of either ten inches or one foot. Such experiments would be perhaps costly, but there is at least one wealthy engineering society, by a committee of which such experiments might be usefully carried out on the structural materials of to-day.

In conclusion, a few words may be said upon the behaviour of the harder kinds of steel plates in which they differ from those of iron. It has been observed by many that some of the steel plates, with an elastic strength as high as 18 tons per square inch combined with a ductile extension as high as 15 per cent. as obtained by the tests of strips of such plates, when in the hands of plate smiths or when built into structures behave very differently to iron with the same apparent mechanical properties. The toughness of good iron plates enables them to gradually dissipate any internal differential molecular strains of tension and compression that may be resident in them as they leave the rolling mills, by differential compression and tension. Steel plates which are comparatively hard, but which when torn asunder in test strips indicate an ultimate extension of as much as 15 per cent., might be expected to do the same. Such, however, is not the case, for the plate has often behaved when built up into a structure as through its ultimate extension was not more than one or two per cent., and like glass, possessed of a high elastic limit but no toughness. Why this should be is not known, but it may be suggested that such being the behaviour, the following may afford some clue to the fact that thick plates, at least of such material, have fractured in various directions, after the structure of which they have formed an integral part has been completed. Most plates before being built into a structure are annealed, but the following remarks apply equally whether annealed or not.

Plates when taken from the rolls or from the annealing oven are generally laid on a flat surface to cool, but whether laid down or stood on edge, cooling takes place somewhat more rapidly towards the corners and edges than at the middle. At first, the whole plate is of the same temperature, which may be

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that of redness. The exterior parts first assume the rigidity of cold steel, and contraction takes place on the interior parts which remain at a higher temperature, and therefore the contraction has taken place under a tensile strain. Thus, if a plate of 1 inch in thickness is considered in illustration, it will be seen that a corner of, say, 6 inches on either edge has an area on the two sides of 36 square inches but it has also the additional effective cooling area of the edges, which adds 12 square inches making for a surface area of 36 square inches a total of 48 square inches of effective cooling area by radiation and evection. If, on the other hand, an area on the two sides at the centre of the plate, of 36 square inches of such surface, be taken into consideration, it will be seen that the edge surface can only be considered as cooling by conduction. Thus the effective cooling area of the outer parts of the plate is much more efficient than the central parts. These outer parts having, then, become rigid and contracted under tension, exert a correspondingly compressive strain upon the interior parts still at a higher temperature, and thus more or less amenable to compression. This tensile strain upon the outer parts or borders of the plate is gradually eliminated as the interior parts cool, and is finally changed into one of compression as the inner parts contract in cooling under a molecular tensile strain, due to the incapacity of the rigid border to follow the inner parts in their contraction. In the cold plate put into a structure, there is thus initial molecular strain differentiating from compression at the edges to tension towards the centre. If the plate is cooled under circumstances inducing unequal cooling, these internal strains are aggravated, and they may possibly be of such magnitude that extraneous strains that would not materially affect a tough iron plate may be sufficient in a harsh steel to cause rupture. Further, when a plate of such a character is being riveted up, every rivet is compressed under a very high strain to make it fill the holes, and thus, acting as a viscous fluid, adds to the strains already tending to destroy the plate.

These remarks are only made as suggestions, and should perhaps have been put in the form of a question, as they are somewhat aside the object of this note, which is to invite discussion on what seems to be the tendency in the production of very mild steel plates, namely, that in the endeavour to remove the difficulties which have attended the use of steel plates of high elastic limit, we seem to be in danger of losing the facilities for producing lighter structures which the application of steel seemed at one time to afford.

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DISCUSSION.

The PRESIDENT, in inviting a discussion on the subject of the paper, said that he thought that the writer was quite correct in stating that the difficulties which engineers experienced in using steel in construction were very much greater when they were dealing with steel plates than when they were dealing with steel in any other form, such as bars and wire.

Mr. SCHÖNHEYDER said that he quite agreed with the author in the opinion that they must look upon the elastic strength of a material rather than upon its ultimate strength in considering its value for structural purposes, for it was of very little use for a material to be able to bear a very high ultimate strain if it changed its form at a much lower limit. It seemed to be principally upon that point that the author had written; but he (Mr. Schönheyder) fancied that the author had taken his stand upon very few and exceptional experiments, for he seemed to come to the conclusion that there was very little difference between the elastic limit of wrought iron and that of steel, and that therefore there was very little advantage in using steel, at any rate in the form of plates. This view was borne out by the table in the paper, according to which iron plates should have an elastic limit of 16 tons, as found by the experiments of Mr. Grieg. He did not say that those experiments were not correct, but the plates must have been exceptional. Roughly, the elastic limit of wrought iron was not more than from 8 to 10 tons, as a rule, instead 16 tons. In the case of wrought iron with an ultimate strength of 20 tons, the elastic limit would generally not be above 10 tons. He knew from some experiments which he made some years ago, and from the statements of no less an authority than Mr. E. A. Cowper, that the elastic limit of wrought iron was usually found much less than the author had given, and it seldom exceeded 8 or 9 tons. The elastic limit of 16 tons which the author had given as that of steel was, perhaps, lower than found in a great many steels. For instance, Dr. Siemens recommended for boilers, steel plates with an ultimate strength of 30 tons and an elastic limit of 15 tons. 15 tons was about 50 per cent. more than the elastic limit of wrought iron, and the extension of the same material, was 20 per cent. In some other experiments upon $\frac{7}{8}$-inch steel plates for boilers, which had been made, to the best of his recollection, by Messrs Denny, of Dumbarton, the ultimate strength was from $27\frac{1}{2}$ to 27·8 tons taken lengthwise and crosswise respectively, and the elastic limit was between 15 and 16

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tons. The extension in 10 inches was 28 per cent. lengthwise, and 20·9 per cent crosswise. Hence it appeared to him that there was a very great advantage in the use of steel plates. They would certainly give from 50 to nearly 100 per cent. more elastic strength than the same thickness of wrought-iron plates. The author gave some experiments by Kirkaldy of Mr. Siemens' mild steel plates, but it would be useful if he would add the length of the specimens, as it was well known that the extension was very different according to the length of the specimens. He had heard the opinion of people who had had to manipulate mild steel, and they all spoke very highly of its character, and said that it was very much better than iron. For instance, they could bend cold angle steel almost flat down, or bend it double without its showing a sign of cracking, and yet its ultimate strength and elastic limit was very high, showing an enormous advantage over wrought iron in respect to ductility. He believed that the angle steel of which he was speaking was Bessemer's. It they attempted to open wrought angle iron (in the cold state) flat, or bend it double, it generally split. On the other hand, he knew that there had been failures of steel plates, especially when steel was first used for boiler plates; but it was now being made very much better than it was five or six years ago. The failure of the boiler plates of the *Livadia* was one of a quite unusual and unexpected kind. He hoped that some day they would have an explanation of it.

Mr. HORSLEY said that he was particularly interested in cast iron, and that he had to use very little steel, except in the form of bars. He should like to ask the author whether experiments had been made to ascertain the contraction and the fractures that were produced in thick plates by cooling, or whether what had been said was merely the author's idea. Had the plates been planed up into strips, and examined for the purpose of ascertaining how much loss there was in cooling. This was done with cast iron, and they knew that there was a loss of 12 or 14 per cent. in strength. The contraction was different round the edges. He had not had much experience of steel boilers, but he should think that the illustration which had been given by the author of the reason the plates sometimes give way, and were not so strong and useful as they ought to be, was excessively good. He should, at present, prefer riding in a ship with plates of good thickness. He had not got quite used to steel ships. It was the same as with wire ropes for pits. When they were first introduced, the men would not go down with them, but now they would not go down with hempen ropes

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if they had wire ones, so that steel had come to the fore in that respect. He quite sympathised with the author as to iron plates for boilers. He had lately examined a boiler which had been in work 22 or 23 years. It had been carefully used, and it was now as good as any of the new ones, or perhaps better, because the iron in it was better than the metal which was now used. He thought that there was a good deal of bad iron and bad steel used now. The quality was not so good as it was formerly. He agreed with the author in his opinion that good wrought iron was better than bad steel.

Mr. BEAUMONT said, with respect to the table which he had put forward, he had intended to say in his paper that the figures related to iron and to steel plates which had been used in very large quantities by a firm of engineers making a very large number of boilers, and they had ascertained those figures by testing a large number of plates. Other figures in the paper related to Siemens steel which had been tested by Mr. Kirkaldy, the test pieces being 10 inches in length. This was merely a summation of a large number of experiments, most of which were given by Kinnear Clarke in his recent book. Both sets of figures were given merely as illustrations of some of the mechanical properties of the very mild steels to which the paper referred, and were not intended to be illustrative of mild steels generally. He had recently seen some tests of other steels made by the Siemens process, which showed a slightly higher elastic limit, and also a much higher tensile strain, but he had not mentioned those plates in the paper, inasmuch as the ultimate strength was rather higher than it was generally considered safe to use for boilers. The diagram * of the plate was merely a suggestion made by analogy from the behaviour of iron and steel in other forms.

Mr. HORSLEY, said that he had recently asked at a factory, where there was some large work going on, what strength of material was used, and he was told that the wrought iron was 9 tons and the steel 18 tons. That agreed with Mr. Schönheyder's statement.

Mr. SCHÖNHEYDER added that it appeared from the paper that there was a disadvantage in the softness of the steel plates because they gave way first at the rivet holes. Instead, however, of that being a disadvantage, as some people consider, he held it to be a positive and very great advantage. By all means, let each rivet act a safety-valve, and let the steam escape and

* A diagram was hung upon the wall illustrative of the suggestions made in the latter part of the paper relating to the internal molecular strains possibly resident in the thicker plates when cooled in the ordinary way.

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prevent an explosion. If it was an advantage that the plates should not stretch at the rivet holes, and that the rivets should not act as safety-valves, then let them have cast-iron boiler plates, because they would not give way gradually, but would burst suddenly. If they could, in testing boilers, get a strain equal to 70 per cent. of the ultimate strength of the steel, that was more than enough, because they had no right in testing to exceed the elastic limit of the material.

Mr. HALPIN said that from looking at the table he should say the plates referred to must have been "Best Yorkshire" plates. Acccording to his knowledge, the elastic limit of "Best Yorkshire" iron plates would run up to the figures the author had given.

Mr. SCHÖNHEYDER said that he believed that the best Yorkshire plates were very seldom used for boiler shells, on account of their high price.

Captain BROWNE said that, with regard to the object of the paper, the author suggested one of two conclusions—either that the engineer was not really trying steel, but was trying a sort of compromise between steel and wrought iron, or else that there was not much hope to be got out of steel at all. The diagram seemed to suggest that there was a bad future for steel altogether, because the harder steel, he presumed, would have more carbon in it, and inasmuch as these strains were assumed not to exist in the same way in wrought iron as they did in steel, one would suppose that as they got harder steel, the state of things represented in the diagrams would be more and more exaggerated. He should like to ask those who had had any experience of steel, whether any attempt had been made to trace the strains which a plate of steel was undergoing by the signs that were seen on the scale. Every time that a steel plate was sheared, there were along the edge which was sheared a number of lines or cracks in the scale, all running more or less parallel to one another. They ran generally diagonally from the edge. In other processes there were other marks in the scale. Those marks were probably the result of something that was going on in the metal underneath.

Mr. WILKINSON JONES said that he should like to know the length of the pieces that were tested in proportion to the sectional area. The length made a great deal of difference in the extension of the sample, and no doubt would make some difference in the elastic limit. He generally made his test pieces 100 millimetres in length by 15 in diameter. The diameter was about one-seventh of the length. He believed that if Mr. Kirkaldy tested a cylinder, he generally made his

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diameter a tenth of the length. Mr. Euverte, in his report on Terrenoire steels, had said that the length made a great deal of difference. His samples were 200 by 30 by 10. He said that had he shortened the sample to 100 millimetres, the extension would have been increased from, say, 6 to 10 per cent. He should therefore say that there would by a difference in the elastic limit if there was a difference in the extension. The author said something about mild steel rails being liable to split, but he (Mr. Jones) did not know how he proved it. Steel rails had now been tried for a long time, and he doubted whether there had been many cases of steel rails with a solid head splitting; of course if they got a ropey head it would be liable to split. He did not think that it had been shown that solid steel rails were likely to split at all, any more than to laminate.

Mr. PENDRED said that he supposed that there was not an engineer who was acquainted with the various properties of iron and steel who had not long since made up his mind that the constructive material of the future must be steel, although they would perhaps continue to use iron on a small scale for special purposes. But until a comparatively recent period—in fact he might say until the Menai tubular bridge was being built, and experiments were carried out by Fairburne on the strength and properties of iron—there was an enormous amount of ignorance as to the strength of that material, and the proper way to work it into a structure in order to get the best result from it. Even the information which Fairburne had given was regarded in the present day as not altogether as sound and trustworthy as it might be. He supposed that no tubular bridge would ever be built again, as the material put into the Menai tubular bridge could be better disposed, weight for weight, in a lattice girder. It appeared that engineers were in very much the same position with regard to steel as they were with regard to iron at the beginning of the railway era. They had to deal with a material about which they knew comparatively very little indeed. He thought that there had been a slight tendency to drift away from the purpose of Mr. Beaumont's paper. The point of the paper was that Mr. Beaumont pointed out that steel had a lower elastic limit, or about the same elastic limit as iron, and therefore that they might just as well use iron as use steel. And Mr. Schönheyder, and two or three other speakers, had pointed out that the iron used in the instances quoted by the author was an altogether exceptional iron. It was worth considering whether it was an exceptional iron, seeing that just such iron was employed in the construction of boilers. He thought that it might be said that up to the present moment a very large

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amount of success had been obtained in the use of steel plates between a quarter of an inch and half an inch thick for boiler shells, and engineers knew pretty well how to manipulate them. Furthermore, steel-makers were beginning to make the proper kind of steel for such purposes; but the moment that engineers went up to steel plates of an inch or an inch and a half thick, such as were now used for marine boilers, they appeared to have a totally different class of metal to deal with, and the very faults that first appeared in thin steel plates, and which had been got rid of gradually in the case of thin plates, were now manifesting themselves in the case of the thick plates, which were used for marine boilers. There were many reasons why engineers should use steel plates for marine boilers. One point was a purely practical one. It was that in making a boiler of 1-inch or $1\frac{1}{8}$-inch plate 13 or 14 feet in diameter, to carry from 80 to 100 pounds to the square inch, it was almost impossible to make a perfectly tight seam even when it was treble riveted. In fact it might be said that it was absolutely impossible to make such a joint tight in an iron boiler, aud there was a continual leaking which injured the plates. But a comparatively tight joint could be made, with very little caulking, if steel was used instead of iron. Another reason why steel was in favour was, that in very large boilers they could not use anything but first-class Yorkshire plates, or plates of equal quality, and these would cost 18*l.* or 20*l.* per ton, while steel plates could be bought for 13*l.* or 14*l.* a ton. In steel boilers certain occurrences took place for which engineers could not account. The case of the *Livadia* was only one out of a dozen that might be named. If they came to investigate why steel plates gave way, it would be found that they were generally flanged by the makers of the plates, not by the boilermakers, and they appeared to be flanged practically at one operation. There was no evidence of hammering. But when these flanged plates came to be worked into a boiler, they often need alteration, and the flange had to be beaten down, perhaps just at the corners. This was done by a smith, and often in a very crude manner. While that operation was being carried on, the plates would crack, the failure being caused probably by the jolting or vibration due to the hammering. In the boiler of the *Livadia*, when the rings came to be put together, one was allowed to fall while it was being lifted into its place by the crane. It struck a block of iron, and bent up in the middle. Nothing was thought of this, and the men imagined that the hoop could be straightened. As soon as they came to straighten it, it was found to be cracked. After that, all the plates, after having

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been drilled and got ready for riveting, were sent back again to the makers and annealed, but the annealing did not save the metal. There was one point which was continually lost sight of in dealing with steel. If they took a strip of iron and bent it over on the anvil, they knew that the iron was in very nearly the same condition as it was before bending. But when a strip of steel was bent over, the chances were that it had such strains set up in it that it was not so strong afterwards as it had been before, and very often it would break under very gentle strains. Again, it was pretty clearly understood that they could not punch steel plates, but they could punch iron plates, or do almost anything they liked with them. Steel was a material which possessed very good qualities, but it had some characteristics which it was useless to ignore, and engineers had yet to find out how to overcome its defects. The complaints with regard to steel always came from the users. The steel-makers all admitted that there was a great deal of bad steel, and that it was useless to deny that there were difficulties in the way of working steel plates; but each maker said that these difficulties had been completely got over by his own firm. He (Mr. Pendred) had asked some steel-makers how it was that they had succeeded in overcoming the difficulties, and they replied that it was not likely that they should make known a process which they had arrived at only after a very large expenditure of time and money, but that the result had been perfectly satisfactory. That was a very encouraging statement, because it showed that if proper care was taken in the selection of the ore and the fuel a trustworthy steel could be produced. As to the length of the samples used for testing, Mr. Kirkaldy invariably employed a length of ten inches, and a diameter of one inch. As to the external indications of strain on samples to which Captain Browne had referred, Mr. Kirkaldy carried out some very interesting experiments on that subject years ago. He took a plate, cut it off at the end, and then described a large number of circles upon it. The greatest possible care was taken in putting the sample into the testing machine, to that the strains should be perfectly parallel, and that there should be no side strain; some hundreds of circles were described on the plate. The speaker drew a diagram on the black board. The plate showed by the distortion of the circles what the nature of the strains was, and the specimen could be seen in Mr. Kirkaldy's museum. A very curious point arose in connection with the specimen, and this was afterwards confirmed by a very large number of experiments which were carried out by Mr. Kirkaldy, although the utmost care was taken to get the strains parallel in right lines

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through the plate, it was absolutely impossible to break a plate about 14 inches wide straight across. It would always break diagonally.

Captain BROWNE, asked whether it was not possible to get the same results by simply watching the scale on the surface of the plate, instead of tracing lines on the plate

Mr. HALPIN said, that with reference to the remarks made, the appearances of the scale changed every moment while the test load was being applied, and the scale would be constantly breaking up, so that they could not get the result due to the appearance of the scale at one particular moment, and there would be no final mark left to show what had been done. The experiment which Mr. Pendred described as having been carried out by means of circles, he (Mr. Halpin) had also seen done by means of squares and diagonal lines. He quite acknowledged that it was necessary to have uniformity in the specimens, and to have a proper length in proportion to the diameter. It was probable that if abnormally proportioned specimens were taken, erroneous results would be arrived at. The purport of the paper seemed to be to demonstrate the necessity of knowing the elastic limit of steel. It was not much good to know merely what amount of load would kill a man or horse. What they needed to know was, how much a man or a horse could carry from day to day in safety; and it would be very expensive to kill a man or a horse simply for the sake of knowing what their ultimate powers of endurance might be, so it was in the case of metal. As yet, they had hardly the slightest knowledge of what the elastic limit of steel or any other substance was, and he thought that they had not any means of ascertaining it, for when steel was loaded with infinitesimal loads they would get elongations, and then cease to get them; and then get elongations again, and again cease to get them; and so they would get a perfectly irregular curve of elongation when the limit of elasticity was once passed, and it was perfectly impossible to say where the limit was. And the limit in one piece of steel might not be repeated once in ten times in other similar specimens. A machine which would ascertain the elastic limit, if such a machine could be devised, would be of inestimable value.

Mr. BEAUMONT, in replying upon the discussion, said that he thought that the object of the paper was stated pretty clearly at the end. In the beginning, it was stated that the object was to draw attention to certain questions which were important to engineers in considering whether they should use mild steel for certain purposes, or what structural advantages they could

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obtain by its use; and secondly, the object was to draw attention to what appeared to be the fact, that instead of having steel capable of bearing very high strains within a high elastic limit, as they were led to expect some years ago, they were obliged to use steel with an elastic limit which was not much greater than that of the best iron, when the steel was purchased and used with regard to its known behaviour when it had to be riveted, punched, flanged, or worked, in some such way. The steel to which the paper referred was, no doubt, a very excellent material where it had not to be worked very much, or where it was not subject to very different strains. The contention was not that the mild steel was not a good material, but that it was not as good a structual material as they were promised years ago. Engineers had been promised steel with certain characteristic properties, which would enable them to make boilers much lighter than they were made of iron; but they were not now getting the material which had been promised, and they found that the steel plates must be nearly as thick as iron plates. The great elongation of the material, and low elastic limit, indicated that some of the properties of the material, as steel, were not retained. They had to use a material which had very great ductility, but a very low elastic limit. The question was whether it was not possible for steel-makers to produce a trustworthy workable material which had a high elastic limit.

The length of the samples to which Mr. Schönheyder had referred was 10 inches. As to the diagram to which Mr. Horsley had referred, he (Mr. Beaumont) had seen no experiments on that subject. It was merely a suggestion that possibly the curious and anomalous behaviour of the thicker steel plates might be explained in the way which he had described. Mr. Pendred had to some extent replied to Captain Browne's remarks as to the behaviour of steel plates. A very interesting paper on that subject by M. Barba* had recently appeared in the Mémoires de la Société des Ingénieurs Civils. Captain Browne had said that the paper led to one of the two conclusions which he stated. However, he (Mr. Beaumont) had already explained that it was not meant that steel was no better than iron for any purpose, but that he wished to point out that in order to get a workable material engineers had to accept a material of great ductility and low elastic limit. In respect to the length of the test pieces of which Mr. Jones had spoken, all the pieces referred to in the second table were 10 inches, and all the others

* Résistance des matériaux. Epreuves de résistance à la traction. Etude sur les allongements des métaux après rupture. Par M. J. Barba. Mémoires Soc. Ing. Civ. Juin 1880, p. 682.

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were 8 inches. With respect to steel rails, Mr. Dudley, of the Pennsylvania railway, had carried out experiments on rails of different degrees of hardness, and had found that very hard steel rails wore away more rapidly than those of tougher quality, and his experiments indicated that tough rails and comparatively soft ones wear longer than very hard ones. Mr. Jones had stated that he usually employed test pieces of 100 millimeters in length. That length was equal to about 4 inches. He (Mr. Beaumont) should certainly say that that was not a good length. Nearly treble that length would certainly be better. The differences which one got in test pieces of different length were certainly very remarkable, and should always be taken into consideration. Mr. Jones, however, had stated that the extension was greater when the test pieces were shorter. It had been usually found that the reverse was the case. Mr. Halpin's remark respecting the iron plates were in support of figures which were given in the paper. He (Mr. Beaumont) had not thought it necessary to give the results of a large number of experiments. He had only given the results of some experiments which had been made upon materials which had been used by well known firms. The paper was not upon the strength of the different materials, but it was intended to indicate the direction in which steelmakers were working in order to get a material with which engineers could feel safe. Mr. Halpin had remarked that it was thought difficult to find where the elastic limit was. Professor Kennedy had recently been expending a very great deal of time and trouble in taking elastic limits with very great exactness, and as the result of a great many tests of different mild steels, he found that there was a point at which great permanent elongation suddenly took place, and that, apparently, an inferior elastic limit was reached at many points within that one, but the set was almost inappreciable, or not sufficient to make him certain as to where the first set took place. Using the machine very much within its power, and taking the indications very carefully with a micrometer, Professor Kennedy found that the curve representing the behaviour of the steel went up by steps of irregular length and rise. For some distance, and up to a certain point, the micrometer indicated that elastic resistance had been passed; but at any point within that distance the set was very small indeed, and he was somewhat uncertain about its amount in the lower part of the curve. There was sufficient indication of the point at which elastic resistance had been permanently destroyed, and that was the point which, he believed, was usually taken as the elastic limit.

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Mr. HALPIN, was understood to add that he had seen a curve such as indicated by Mr. Beaumont plotted for Whitworth and other steel, but the irregularity had never been accounted for.

The PRESIDENT, in closing the subject, said that they might congratulate Mr. Beaumont upon the very excellent discussion which his paper had produced. There was no doubt that what Mr. Beaumont wished to call attention to was the fact that steel, in order to be of the full usefulness to the engineer which it was formerly intended to be, ought to have a very much greater ultimate strength than that which was at present manufactured had for general use. He believed, that that was the real point upon which Mr. Beaumont wished to raise a discussion. It was strange that there should be such a difference between the use of iron and the use of steel, considering that they seemed to know the chemical constituents of steel very minutely, which differed little from those of iron, and that they had also advanced very much indeed in its manufacture. Wherever steel had been used in a straight, plain shape as it came from the manufactory, it seemed to have stood very well. But as soon as secondary manipulation was made use of a difficulty presented itself, and it was in this respect that steel had been found to fail in so many instances. Until manufacturers or scientists or chemists found some way of making a more uniform material far all the manipulations through which it had to pass, steel would always be uncertain, and as long as it was uncertain it would be a material which engineers would hesitate to use freely. He had himself not yet dared to make steel boilers for the use of his clients, but had always recommended best Yorkshire, or double best Staffordshire iron, for the outside shells. The engineer, who had to take the material as it was given to him, must have some certainty about it before he could use it with confidence; until such unforseen failures, as those which had been referred to, were no longer heard of, they must not be very sanguine about the use of steel in boilers or in other structures which endangered life through their failure, and for which the steel had to be manipulated a second time.

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November 1st, 1880.

CHARLES HORSLEY, VICE-PRESIDENT, IN THE CHAIR.

ENGINEERING NOTES ON CYPRUS.

By CHARLES J. ALFORD.

Two years have now passed away since the island of Cyprus was added to the British dominions, and yet the Royal Commissioner says, in his lately published report, that "The only thing we want is water." Surely there is a fault somewhere: Cyprus was once well irrigated, and was then the garden of the East, why should it not be so again? Is it that water cannot now be found in Cyprus? or have English engineers at last met with an insuperable difficulty, and are not able to find it? These are some of the questions which the author of this paper places before the Society for discussion, and to assist in the solution of which he will endeavour to furnish such data as his experiences, whilst making a general report on the island in the summer of 1878 for Messrs. Docwra and Son, may enable him to give.

In the first place it will be well to take a general survey of the island, as represented by the accompanying map, before taking note of the details of each separate district.

A glance at the map shows that the island is naturally divisable into three distinct regions. Along the whole of the northern coast is a range of hills of from 1000 to 3000 feet in height, shelving to the sea on their northern side, and on the southern throwing out spurs into the large central valley, which we may consider as region number two. These hills are composed of jurassic limestones, flanked with sandstones of a more or less argillaceous character, penetrated in some places by eruptions of trachyte. Through the whole of the centre of the island extends a large, flat, alluvial plain of some 100 kilometres in length by about 40 in width. About in the centre of this plain is situated the city of Nicosia, the nominal capital of

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the island. This plain is covered with a rich alluvial soil of, in some places, 10 to 20 feet in depth. In the rainy season two considerable streams run, one east and one west, to the sea, but as soon as the rains are over these dry, and during nine months out of the twelve, all this region is a dry, arid desert, covered in places with a layer of mud which the winter floods have left behind. It is here that the irrigation question becomes of importance, for certain it is that until something is done to control the water in the winter, and to supply it during the summer, this once most fruitful plain must remain as it is at present, almost a desert. The southern division of the island consists of lofty mountains, culminating in the peak of Troodos, over 7000 feet in height, and sloping gently to the sea towards

the south-west in a series of spurs, with beautiful valleys between them, this constituting, now, the most fruitful part of the island, though it also suffers from inundation in winter and drought in summer. The mountains of this district are composed of limestones and shales of Silurian origin, penetrated by eruptions of granite, and traversed by porphyritic dykes and veins of

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quartz. Towards the sea these primary rocks are overlaid by tertiary limestones, which are again in places deeply covered with recent gravels, sands, and clays, beds of gypsum occurring in places. All round the island runs a narrow, level beach, backed by gently rising hills, through which the winter torrents have cut deep ravines.

The principal towns of the island, which give their names also to the surrounding district, are Larnaca, Nicosia, Famagosta, Kyrenia, Ktima or Baffo, and Limasol. The first three of these only being of importance, regarding the questions under discussion in the present paper, the three latter may be passed over with a brief description. Kyrenia is situated on the northern coast, shut off from the great plain of the interior by the chain of mountains already mentioned, its communication with Nicosia being kept up through a pass. The roadstead of Kyrenia has safe anchorage, and the district around the town is fruitful, and suffers less from the summer drought than any in the island. The town of Ktima, or, as it is more generally called after its surrounding district, Baffo, is situated on the south-west coast, Limasol being some 60 kilometres to the eastward. These two towns owe their importance only to the rich agricultural districts by which they are backed, the produce of which is brought to them for shipment. Limasol has a large sheltered roadstead and good anchorage, though the water is very shallow near to the town. This port will most probably become of importance as roads, and means of communication with the interior, become developed, also, if the mines of Cyprus are ever again opened up, Limasol will, from its position, naturally become the shipping port for their produce.

Larnaca is the landing place on arrival in Cyprus, and the first view of the island on arriving in that roadstead is not inviting, especially if the traveller arrives there during the dry summer months. A low, sandy shore, backed by a line of gently rising hills, a few scattered palm trees, with a line of dilapidated houses on the beach, two or three church towers and minarets, and an old Turkish fort. Landing-place, there is none, excepting only two little wooden jetties of a few yards in length and of the most rickety construction. Indeed, only a few weeks ago the newspapers reported the case of several persons having been drowned whilst attempting to land. The water is very shallow to a long distance from the shore, which occasions a heavy surf whenever the wind is at all strong from the south or south-east. The anchorage about a mile from the shore is

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good, the bottom being hard sand. The construction of a wet dock at Larnaca would be a matter of comparative ease, some salt lagoons to the westward of the town might by dredging be converted into a very convenient harbour, or a harbour might readily be constructed by placing a breakwater off the town and dredging inside of it. Larnaca is, and must remain, from its position, the chief mercantile port of Cyprus, and to let it remain as it is at present is simply a disgrace to England as an engineering nation. The town itself is as much in want of improvement as the harbour, sanitary arrangements are of the most primitive description, gas there is none. Water is brought from the hills some 15 kilometres distant by an open aqueduct, being on its way heated by the sun and polluted by all kinds of garbage being thrown or falling into it. A good road has been made from Larnaca to the capital town of Nicosia, which is at present the only road in the island worthy of the name. Nicosia, the capital of the island is a large walled town, of from thirty to forty thousand inhabitants, situated in the centre of the large interior plain of the island. Like all eastern towns, the streets are narrow and partially covered in to keep out the intense heat of the sun, badly paved, and, until lately, very dirty. The drainage of the town is very defective, but this subject will come under consideration with the subject of drainage in general. The water for the use of the town of Nicosia is brought from the mountains to the northward by an open aqueduct during the dry season when the streams have run dry. Communication with the sea is kept up through Larnaca and Kyrenia, the road to the former being the easiest, though the distance is much greater. The road from Nicosia to Famagosta scarcely deserves the name, being but a track across the level plain, which is dry and dusty as the Sahara in the hot months, and covered with rank vegetation in the wet ones. A few miserable villages are scattered over the plain, and where a well has been made, and irrigation is kept up, the luxuriant growth of corn and vegetables serves to show what the land would produce under less disadvantageous circumstances.

Famagosta is at present nothing but a ruin, since the Turks took the place from the Venetians, two hundred years ago, it has been in its present state, nothing now remains of its once famous harbour but the natural reef of rocks which enclosed the basin, and the ruined town is almost deserted, the Christian village of Varoschia, about a mile from it, having quite taken

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the place of the old city as a dwelling place. Famagosta is nevertheless the best position in the island for a naval station. With what ought to be a splendid agricultural country at its back, and one offering no difficulties to the construction of a line of railway to all parts of the island, it is admirably fitted to become the base for the operations of our fleet in the Levant. The old harbour of the Venetians only requires cleaning out to become a useful inner harbour, whilst an outside breakwater would enclose a space which it would be easy to dredge into a large and commodious harbour for the largest ships. The flat, sandy shore offers every facility for the cheap construction of dry and wet docks. Here again the want is fresh water, and this want appears to be the only one the means of overcoming which are not at present apparent. Having thus briefly described the principal districts and cities of Cyprus, it may not be out of place to notice the natural productions of the island, both vegetable and mineral, before entering upon the study of the means necessary to be used to make them profitable. Almost the only export from Cyprus at present is the carob pod. These trees grow in profusion through the whole of the districts of Baffo and Limasol. About the month of April the branches are lopped off, and shoots grafted on; then the tree soon becomes covered with pods, which quickly turn black and ripen, being ready for picking by August. These pods until lately have been only used as food for cattle, but a French firm are now distilling an excellent brandy from them. The author is of opinion that a source of great wealth may be found in the cultivation of these trees. In the western part of the district of Baffo silkworms are cultivated to a small extent, and also orange and lavender waters, and myrtle oil, are distilled. On the mountain slopes, pines, firs, ash, and oak trees grow, though trees have been almost exterminated throughout the island, as will be hereafter noticed. Corn, barley, vines, and figs are cultivated to a certain extent round the more prosperous villages, but cotton, saffron, rhubarb, dates, walnuts, and many other articles, once the wealth of Cyprus, appear to be almost entirely neglected. It is said that Cyprus produced to the Venetians 2,000,000 gold ducats (about 800,000*l.* sterling) a year nett profit, why should it not do the same to England?

The principal mineral productions of the island of Cyprus are copper, lead, iron, lignite, asbestos, and salt; very valuable precious stones were at one time, also, found in the beds of the

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mountain torrents in the district of Baffo. All the indications of mineral deposits which the author of this paper has himself seen have been in the south-western part of the island, though he has heard rumours of some in the mountains of the extreme north-east.

Near the village of Lithrodonda the author discovered some very ancient copper workings, and traced for some distance the vein on which the workings had been made. Large heaps of scoriæ showed that smelting had been done on the spot, and traces of the old mining village were everywhere around. The ore had been well worked, for the scoriæ, on analysis, gave only about 1 per cent. of copper as remaining in it. The analysis of a specimen of scoriæ was as follows:—

Copper	1·06
Iron	8·50
Silica	46·00
Alumina, with traces of nickel and lead	44·44
	100·00

The vein which had been worked at this place was found to run from north-east to south-west, being, where seen crossing the bed of a stream, about 6 feet in width, with copper pyrites and the green carbonate of copper showing distinctly in places. A specimen taken from the outcrop to the vein gave, on analysis:—

Copper	14·50
Iron	22·00
Lead	3·50
Silica, earthy matter, and traces of silver	60·00
	100·00

This place was evidently the site of one of the once renowned copper mines of Cyprus.

Passing west from the village of Lithrodonda, and crossing the pass of Macherà into the province of Baffo, the author met with many indications of mineral veins and traces of ancient work. Copper and argentiferous galena appearing to be the prevailing mineral productions of this district. As the author had the opportunity only of making a very superficial observation, he cannot speak as to the existence of other minerals, but he

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has little doubt that with proper examination of the district others will be found. On the western slopes of the mountains in the district of Baffo, very fine specimens of argentiferous galena have been met with, one of which showed, on analysis:—

Lead	66·20
Iron	2·50
Sulphur	13·00
Earthy matter, traces of silver, &c.	18·30
	100·00.

Silver, 38 oz. per ton.

In the same region very promising specimens of asbestos have also been found, also lignite occurs in places in small beds in the tertiary formations nearer the coast. At one time it is said that very valuable rubies and other precious stones were found in the beds of the mountain torrents in this district, but of this the author can speak only from hearsay.

The absence of roads in the island entirely precludes the possibility of any attempt to open up mineral deposits at present in Cyprus, the only means of transport in these mountain districts being the shoulders of men, and as the natives have the greatest aversion to work of any kind, even this is not easily obtainable.

In entering on the main question of the water supply of Cyprus, it will be well, firstly, to endeavour to trace the causes which have changed the climate of the island since the days of its prosperity, and, whilst lessening the rainfall, have rendered it more violent and irregular. In the author's opinion, the first of these causes is the total destruction of the forests which once covered the mountain sides. For years during the rule, or misrule, of the Turks, trees have been cut down or burnt at will by everyone, but none have ever been planted, and so, consequently, they have nearly all disappeared. Had it been the avowed object of the people to clear the country of trees, it could not have been done more thoroughly; for, with the exception of the carob trees, they seem to allow nothing to grow larger than a walking stick anywhere within easy reach. Sometimes even setting fire to a fine tree in mere wantonness, for the pleasure of seeing it burn. The natural sequence of this is that the mountain sides are bare, there are no trees to attract the rain clouds, and no roots in the earth to prevent the rapid dispersion of the water when the rain does fall. The rain clouds pass over the island to the mountains of Lebanon,

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or break on the tops of Troodos and the other higher peaks, rushing down into the valleys and plains, and quickly away to the sea, doing more damage than good, so that the condition of the agricultural lands is constantly one of either flood or drought. One other cause of the diminished rainfall is also probably the steady advance of the sand of the Asiatic deserts to the westward; slowly, but very surely, the sandy tide rolls on, converting what was once the garden of the world into a scorching desert; miles and miles of Palestine are now thus covered, and doubtless the drying of the air from this cause has something to do with the lessened rainfall in Cyprus and the adjacent lands. But we have to deal only with preventable causes, not with this one which no human hand can stay. The first thing, doubtless, to be done is to stop the destruction of the trees, and to plant again all over the mountain sides. This is, to a small extent, now being done, and recent legislation, if properly enforced, will doubtless have the desired effect of restoring the forests, and with them a more equable rainfall. Meanwhile, the existing rainfall should be made use of to its uttermost extent by building reservoirs, banking the streams in the plains, and bringing the waste of water into due control. Water would also be met with by sinking wells in suitable places. The conformation of the hills of Silurian and other impervious limestone suggests the idea that in many places lodgements of subterraneous water must exist ready for the formation of wells, but boring only can determine this. A glance at the geological section attached to the map of the island which accompanies this paper will show what the author considers to be the formation of the substratum, and if the impervious rocks do not lie too deep under the central plain, a plentiful supply of water ought to be met with in the hollows which the undulations of their strata will probably make, and which should correspond, to a certain extent, with the visible hollows and valleys between the spurs of the hills above. Local experience must make its own rules in this, as in every other case, but from the author's personal observations he has not the slightest reason to doubt the existence of a plentiful supply of water in Cyprus.

Regarding the water supply of the principal towns. Famagosta must be supplied by wells, or by a storage reservoir filled from the summer streams. The two other towns, Nicosia and Larnaca, only require their present supply to be put underground in pipes, in place of the existing open aqueducts, and a storage reservoir to be built at the source of supply, and they

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will be as well off as need be, the water being at its source very pure and good.

Next to water, perhaps the greatest want in Cyprus is means of communication. Roads there are practically none, excepting only the one already mentioned as having been constructed by our Indian troops at the beginning of the occupation; indeed, the author, whilst passing from Limasol to Larnaca, had to ride at times in the sea, the beach being less impassable than the track above. Through the great central plain a railway would be most easy to construct. The ground is almost absolutely level, and ballast is at hand in the river bed. If Famagosta is ever made into a naval station, this railway will become a necessity as a means for the rapid transit of troops to and from the higher and more healthy regions, and for the conveyance of agricultural produce to the coast it would be invaluable.

A paper on the engineering prospects of Cyprus would be incomplete without some remarks on labour and material, the engineer's necessaries. The natives of Cyprus may be put down at once as well nigh useless to the engineer, physical weakness, combined with laziness bred of long habit of idleness, puts them out of the useful category, and the class of half-bred Arab ruffians from the mainland are, from their ignorance and violent intractable dispositions, but little better, though under management their physical strength may be of use. Perhaps the better plan would be for an engineer about to commence any work in Cyprus to at once import his men from Italy. Italians are always willing to engage themselves on foreign work for a time, and when carefully selected are good and trustworthy men. Also the Italian language is so generally understood in Cyprus, that they can get on better than others with those they fall in with there. The author would specially recommend men of Tuscany or Piedmont. Almost all the crude material required by the engineer will be found in the island. Building stone in great quantities is exported from Cyprus to Egypt and other places. Lime, sand, and brick earth are plentiful. Ballast for roads or railways is ready to hand. Timber is wanting, but any quantity of rough ash and small oak may be had from the adjacent coasts. All ironwork, tools, &c., must of course come from the western countries, cement from Italy or Marseilles.

One of the greatest obstacles to the progress of Cyprus since its occupation by the British until now, has been, in the author's opinion, the great uncertainty which has been felt as to the

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intentions of the Government regarding it. If there remains any chance of the island being again handed over to the Turkish Government of course no one with any common sense would put capital into it. Another reason is the very uncertain tenure of land in the island, almost every plot of land is said to be owned by the Sultan, the Government, and by half a dozen people besides, so that a purchaser seems to be unable to know what title he can get for the land he buys. Many of the old inhabitants who left the country when under the Turkish rule have now returned, and try to regain their deserted property, which by this time has perhaps been seized upon and sold two or three times over. Under these circumstances Cyprus is likely to become a happy hunting ground for lawyers. The late transfer of the government of Cyprus from the Foreign to the Colonial Office may be perhaps taken as a sign that our hold on the island is not to be given up. This will go a long way towards inducing capitalists to interest themselves in Cyprian affairs. Just and fair legislation must follow as a matter of course, and there cannot be a doubt that, with the necessary engineering improvements carried out, with English energy and English money, and with a wise and firm policy to govern the very mixed population of the island, Cyprus will in time become an ornament to the British Crown.

DISCUSSION.

Mr. CARRUTHERS said he was surprised at being called upon by the President, as he had never been to Cyprus, and could therefore give no information about it. He had, however, lived in Mauritius, which in many respects was similar to Cyprus. The author, and everyone else, himself included, abused the Turk for his mis-government in allowing so fine an island to be destroyed, but in Mauritius, England could show just as good a specimen of mis-management and mis-government. There, also, the timber had been destroyed, and in consequence a large part of the island had become unfit for occupation. The north shore of the Mauritius consists of an extensive and once fertile plain, which a few years ago produced vast crops of sugar, and was divided into estates worth 40,000*l.* or 50,000*l.* each; it is now simply abandoned, and, like the plain round Nicosia, has become almost a desert. The colonial government wishes to buy the land, which it could probably do

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for a pound an acre, including the buildings and machinery; but the colonial office will not grant the necessary permission. In the meantime, cultivation has gone to the central parts of the island, in which new estates are being rapidly cleared. A railway was built through the once fertile north plain, and from which great expectations were entertained, but which now pays nothing. At the same time, a railway was also built for the purpose of developing the midland part of the island, but from which the most sanguine expected no profit; it, however, pays very handsomely, for it passes through the only part of the island in which sugar can now be grown. Exactly what had gone on in Cyprus was now taking place in Mauritius; the timber is being destroyed in the most reckless manner, and in another ten years, he supposed, the midland would be as useless as the north part of the island, and Mauritius would then be in exactly the same state as Cyprus. In order to restore the fertility of the north plain, and to maintain that of the midland, the whole of the mountains, and a part of the plain, must be again clothed in forest; this would not increase the rainfall, for that registered is, even in the north, as large as it ever was, but it would keep the rain on the ground, and would thus maintain the moist atmosphere necessary to plant life. One third of the island should certainly be under forest. If the English government wish to restore Cyprus to its former state of fertility, they must adopt the same method. If the mountains were fenced in, and cattle and trespassers thus kept away, the timber would grow again without further care; but this would require fifty years, and something more must be done in the meantime. Dams and irrigation canals are required; he did not see why they could not profitably be constructed, although irrigation requires a great deal more water than is generally supposed. The whole of the plain could not probably be irrigated, but the most suitable parts might be selected. The author states that water may be obtained from wells, and in that case pumping might be sufficient, as in many parts of India, to convert the barren plain into one on which almost anything could be grown.

The CHAIRMAN said that he had not visited Cyprus, but it appeared to him that a great deal depended upon whether the English Government intended to retain it or not. He did not think that Englishmen would spend their money in Cyprus unless they first knew that. It would not do for Englishmen to waste their money by putting it into Cyprus if the Turks

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were to have the land back again at 1*l.* an acre with machinery included. There were some very interesting remarks in the paper about the making of docks, &c., the same observations would apply in that respect. When Englishmen could invest their money in so many well watered countries, he fancied that they would go farther afield than Cyprus.

Mr. R. F. ALFORD asked the author whether he thought the present harbour of Famagosta could be made into a harbour for large ironclads, and a naval station, without any very great expense. He also wished to know in which direction the author proposed building the breakwater in case a more commodious port was found necessary, and which way the wind generally sets; also whether there would be any great chance of getting the breakwater silted up with sand, as in the case of Port Elizabeth.

Mr. CARRUTHERS said that the construction and improving of a harbour like Famagosta was of such importance, that it would be very important if the author could satisfy the meeting on the subject of the direction of the winds. He assumed that Cyprus was very much like Egypt, and had a north wind ten months in the year.

Mr. RIGG, referring to the question of the cutting down of trees, said that he heard Dr. Hooker give an address at the Royal Institution on the destruction of the American forests over which he had travelled last year. Dr. Hooker there found the most ruthless devastation in progress, and it would assuredly produce the same evils from which Cyprus suffered. The American Government were now reserving small portions of the country in which the trees should not be destroyed; and the question of whether the American continent would not suffer from serious floods in winter, want of water in summer, and greater climatic variation, was attracting very serious attention on the part of thoughtful Americans. He believed that the same thing had happened near the sources of the river Rhone, because the Swiss forests had been cut down, and the Rhone was subject to very serious floods in winter, and insufficient water in summer. Similar results are being produced, on a smaller scale, in our own country; the streams are gradually getting lower and lower in dry seasons, and we are subject to floods, as anyone who had recently travelled through the midlands, could not fail to observe. Here this effect might be caused partially by cutting down the trees, but principally, no doubt, by drainage of the uplands; both causes having the effect

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of sending the rainfall down all at once. So that to remove these evils, the first thing to do, as the author had said, was to plant trees, and they would be cured by the remedy which nature itself had provided.

Mr. CONRADI said that the author had said that railways ought to be introduced into Cyprus. He wished to ask the author whether cheap railways or tramways would answer the purpose. He also wished to know whether any commercial result would be obtained from the construction of tramways, and what was the nature of the ground in Cyprus, in regard to the practicability of laying such lines.

Mr. ALFORD, in reply, said, with regard to the harbour of Famagosta, that the prevailing winds were northerly, and that whenever a gale blew it was a Levant gale from the north-east. The harbour itself was a very fine one in the time of the Venetians; but it must be remembered that the vessels of the Venetians were very small ones indeed. The inner harbour, of which he had spoken in the paper, was surrounded by a reef of rocks; and there would, probably, be from 14 to 20 feet of water in it if it was dredged out. At present there was not 6 feet in some places. The harbour had simply silted up. This harbour, however, would be a very small one. As to taking an ironclad into it, perhaps one ironclad would go in, but it would fill up the harbour altogether. However, a breakwater might be constructed outside the old harbour, somewhat in the style of that which had been made lately at Genoa. It would be a large breakwater running out on comparatively shallow ground, the inside being then dredged out. The bottom was very hard sand, and a breakwater would probably stand upon it, and might be carried out almost any distance. It was only a question of expense. The farther it went out, the larger it would have to be, and the more it would cost; but the farther it went, the larger would be the harbour which it would enclose, and the greater the number of the vessels which could be taken into it. As to docks, there were lagoons close by Famagosta which could very well be deepened, and made into wet and dry docks. The ground consisted of the same hard sand, and could be easily worked, and it would stand very well. The same remark would apply as to railways. A railway, or tramway, or anything of the kind would answer the purpose. Probably, the cheaper it was, the better it would be. The great object would be rapid transit up to the higher part of the island, for the purpose of bringing down troops, or anything

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that we wanted to bring down to Famagosta. There was every requisite there for a railway. The ground was hard sand, covered with drift, shingle, and other material of that kind. There was a dry river bed full of ballast. Everything was there ready to hand. Of course a tramway would serve equally as well as a railway. The floods must be provided for in the first instance, otherwise they would wash away railway, tramway, or anything else. The floods ran down and cut 10 or 15 feet through the surface soil to the rocks below. When once the floods were taken in hand for irrigation purposes, and the water dammed back, it would not sweep down any more. As to commercial results for a railway, there was, at present, scarcely anything in the way of private traffic for it to do. The only use of it would be for Government purposes. Every inch of the plain consisted of the finest land which one could wish to see. Riding over this plain one's horse's hoof would turn up fine rich mould all the way across from Famagosta to Nicosia, if the ground was dry. Round some of the small villages, where they had water, everything grew with the greatest luxuriance, showing what might be done with careful cultivation.

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December 6th, 1880.

JOSEPH BERNAYS, PRESIDENT, IN THE CHAIR.

THE NATIONAL VALUE OF CHEAP PATENTS.

By FRANK W. GRIERSON, Mem. Physical Soc. Lon., and Assoc. Inst. Naval Archts.

What is a patent? A patent is a title deed granted by the law to any man who creates or finds out some new and useful method or process of manufacture, or new combination of material, or any improvement on existing processes or combinations. This title deed secures to him for a limited time the right of ownership in his creation or invention. A patent to be valid must be granted for something new and original, and therefore the number of patents granted in any given term show the advance made within that term upon the previous state of things. The greater the number of patents granted therefore, the greater the number of steps we make in advance. If we do not advance, or if we do not keep pace with our competitors, it is obvious that we shall be left behind by other nations. It is consequently our interest—in fact an absolute necessity for us—to make our advance as rapid and as easy as possible. How is this to be done? This can be done only by removing every obstacle that stands in the way of our progress. A mere glance around shows us the indisputable fact that invention is the foundation of all our prosperity, and that our material advancement is due solely thereto. The mere existence of boundless natural resources cannot profit any nation without invention to practically develop them.

The most inventive nation must necessarily be the most prosperous, and indeed the most powerful. We have been the most prosperous nation in the world, and we have certainly owed this proud position to the fact of our having been the most practical and inventive nation, and therefore always in advance; we look back and see that the great majority of inventions that have revolutionised the world have emanated from Britain.

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What do we find now? The United States are not only closely treading on our heels in many of our long-established industries, even in our own country, but they have driven and are driving us out of some foreign markets, and are admittedly ahead of us in founding new manufactures. Why is this? This question is one of the most important and necessary that we can ask ourselves. The reason the United States are thus overtaking us is because the Americans take the exactly opposite view to that we do of the practical value of invention.

To have invention we must of course have inventors, but inventors, like all other men, do not work for the mere sake of working, but for their own advantage; in obtaining an advantage for themselves they confer upon the whole nation a much greater advantage. It is therefore our greatest wisdom to afford to the inventor the desired advantage as readily and cheaply as we can. The interests of inventors and those of the public are not antagonistic, but are practically identical, as experience has conclusively proved. The advantage an inventor seeks for is secured to him by a patent; patents should therefore be granted at as low a cost as possible.

The view that as a nation we have always taken of patents—which view is exemplified by our present patent law—is that they are hateful monopolies, and stand in the way of manufacturers and others wishing to avail themselves of the inventive genius of the nation, and that without patents invention and scientific discovery would be free and unhampered. It is evident, however, that cheap patents tend to break up any monopoly by inducing many men to enter upon the same remunerative field. In accordance with the old view just stated patents have always been very costly in this country. The present stamp duties on a British patent amount to the large sum of 175*l*. This high sum acts as a protection on things as they are, and prevents much improvement. The view on which our present law was founded is not a just one, as the patentee does not prevent anyone from doing anything he had been able to do before; on the contrary, he is desirous of providing improved processes and means of doing what has not before been possible, or of doing something in a quicker and more economical manner than has before been possible. He is always anxious to get his invention—the result of his brain and hand work—extensively known and used, otherwise he can derive no advantage from it. Inventions are very seldom "happy thoughts," they are nearly always the result of much consideration and many experiments, neither of which would be undertaken for the mere love of the work, but which *are* undertaken in the

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hope of a reward in the form of a successful patent. The patentee has an obvious incentive for pushing his invention, and in doing all he can to get it known and adopted; if it is not an improvement it will certainly not be adopted, but if it is an improvement it will be adopted only as a consequence of the persistent efforts of its inventor, and by its adoption a step in advance has been made. The proofs of this are very numerous. Inventions which are not the subjects of patents have no one to push and advocate their introduction; they are without any guardians, and have been well styled "orphan" inventions by the British Association Committee. Though at everyone's service they are very rarely made use of, as no one has any particular interest in bringing them forward, and thus they often fail to cause any real advance to be made. It is therefore for the good of the nation that an invention should be the subject of a patent, and so be the property of some one to whose individual advantage it would be to make it as prominent as possible. A patented invention becomes an "orphan" invention if the patent is allowed to lapse before there has been sufficient time for making the invention prominently known. The early lapse of patents is therefore detrimental to the interests of the nation. We know that inventors are often in advance of their age. As has been clearly pointed out by "H. N. C." in a letter to the *Times*:—

"The art of inventing is the art of making savings. An article is produced at a certain cost—say, a watch for 4*l*. By means of labour-saving machinery the same article is produced for 3*l*. Now, if a million such watches are wanted every year, the saving—i. e. the value of the invention—is clearly a million annually, but a very small proportion of this goes into the pocket of the inventor. It is the consumer who chiefly benefits. He gets his watch after a while nearly 20*s*. cheaper than he used to do. The consumer, therefore, . . . should regard the inventor as a man to be by all means encouraged.

"The inventor has, in fact, no *status* at all, except as giving more for the same money, or the same thing for less money than heretofore. If this were more distinctly and widely understood and appreciated, it would not be long before the labours of inventors would be protected as cheaply, as long, and as well as the publications of authors; and in that case there is no reason why the Englishman should not threaten the proud position of the American as 'the most prominent inventor in the world.'"

One objection that is made to cheap patents is that many persons might devote too much time to invention and experi-

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ment, to the neglect of their daily occupation, and therefore to their impoverishment. What does this objection amount to? It means that because certain persons are too sanguine or somewhat wanting in common sense, therefore the whole community is to suffer. This seems a very frivolous objection. We might as well propose to prohibit the general use of knives because now and then they are used to inflict serious injuries. Another objection is that were patents cheap many useless ones would be taken out. Admitting this to be the case, no harm could possibly result; they would cost the country nothing, they would remain on record at the Patent Office as a warning to others, and the inventor would be the only man to suffer. On the other hand, it must be remembered that high stamp duties suppress and banish good inventions as well as useless ones. Unfortunately men are not endowed with brains in proportion to their wealth, but wealth by our present system is made the only standard of merit.

Let us compare the British scale of stamp duties on patents with that of the United States, taking only those compulsory stamp duties payable on an unopposed patent. I may remark that I have obtained all the statistics given in this paper from the official records in the Patent Office library. The following are the stamp duties to be paid in this country:—

GREAT BRITAIN.

DURATION OF PATENT, 14 YEARS.

On petition of grant for letters patent ..	(stamp duty)	£5
On certificate of notice to proceed	„	5
On warrant of law officer for patent ..	„	5
On sealing letters patent	„	5
On filing complete specification	„	5
On letters patent before end of 3rd year	„	50
On letters patent before end of 7th year	„	100
Total stamp duties on one patent		£175

The following are those payable in the United States:—

THE UNITED STATES.

DURATION OF PATENT, 17 YEARS.

On application for letters patent	(stamp duty)	£3
On issue of letters patent		4
Total stamp duties on one patent		£7

An opposed patent incurs further duties in both countries, but the same proportional difference is found in favour of the United States.

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Let us compare the effects of these two systems—ours costly and complicated—theirs, cheap and simple. Last year compares exceptionally favourably for us, as it was a very slack year in the American Patent Office but a busy one in ours; there were in that year fewer patents granted in the United States than in any of the previous five years, and a greater number of patents granted in this country than in any of the preceding ten years. We find that, not including designs, there were about 20,000 patents applied for, and 12,820 granted in the United States against 5338 patents applied for, and 3461 granted in this country.

Taking an average of ten years, the figures show still more to our disadvantage, as will be seen by the following table:—

COMPARATIVE TABLE FOR THE TEN YEARS 1870–1879.

Year.	United States.		Great Britain.					
	Applications for Patents.	Patents granted.	Applications for Patents.	Patents granted.	£50 Stamp Duty.		£100 Stamp Duty.	
					Paid.	Number	Paid.	Number
1863			3309	2066	1866	632	1870	215
1864			3260	2002	1867	550	1871	178
1865			3386	2159	1868	582	1872	193
1866			3453	2100	1869	574	1873	227
1867			3723	2253	.....	.....	1874	260
1868			3991	2456	1870	619	1875	272
1869			3786	2366	1871	729	1876	309
.....	.....	.....	.....	.....	1872	793	1877	280
1870	19,171	13,321	3405	2140	1873	738	1878	307
1871	19,472	13,033	3529	2338	1874	819	1879	291
1872	18,246	13,590	3970	2734	1875	853		
1873	20,414	12,864	4294	2906	1876	856		
1874	21,602	13,599	4492	3104	1877	953		
1875	21,638	14,837	4561	3049	1878	895		
1876	21,425	15,595	5069	3367	1879	947		
1877	20,947	14,187	4959	3259				
1878	20,898	13,444	5343	3438				
1879	20,693	13,213	5338	3461				

The above figures for Great Britain are for patents only, but those for the United States include designs, which are not given separately in the American reports. The number of designs applied for in 1879 in the United States was about 700, which is in the ratio of 3½ per cent. on the applications of that year; deducting this proportion from the total applications above, and 3 per cent. from the total grants (allowing the ½ per cent.

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for rejections), we obtain the following figures as the average of patents of the ten years:—

	United States.		Great Britain.					
	Applications for Patents.	Patents granted.	Applications for Patents.	Patents granted.	£50 Stamp Duty.		£100 Stamp Duty.	
					Paid.	Number	Paid.	Number
Average with Designs	20,451	13,769						
Deduct for Designs	681	413						
Average of Patents	19,770	13,355	4496	2980	—	820	—	253

I must explain that I have been obliged to take the figures for Great Britain as far back as 1863, so as to obtain ten years in the last column. The averages are calculated from the figures *below* the dotted cross line—that is, from the last ten years in each case.

It is noteworthy that our 50*l.* stamp duty at the end of the third year kills about 70 per cent. of the patents granted, and that our 100*l.* duty at the end of the seventh year destroys nearly 20 per cent. more, leaving only 10 or 11 per cent. to complete the full term of fourteen years. The effect of these crushing duties is that while on 31st December, 1879, there were in this country only 15,755 patents in force, in the United States there were more than 220,000, not including designs. The United States thus have thirteen times as many patents in force simultaneously as we have, or, allowing for difference in population, eight times as many as we have, and therefore make eight efforts to advance for each one that we make. During the last ten years, 22,868 British patents have been crushed out by these heavy stamp duties, viz:—18,511 by the 50*l.* duty, and 4357 by the 100*l.* duty. An American patent once granted lasts the full term of seventeen years, without further payment; whereas a British patent lasts on an average only five years, in consequence of so many being unable to pay the duties at the end of the third and seventh years. There is therefore a very much greater incentive to invention, and consequently to national progress, in the United States, than there is here. While of American patents the whole number issued, i. e. 100 per cent.,

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lasts the full term of seventeen years, only 11·18 per cent. of the British patents granted last the full term of fourteen years. The result of this we see everywhere around us in the enormous import of American tools and manufactured goods of varied descriptions, and in the continuous flow of our skilled artizans to the United States.

That the Americans fully appreciate the national benefit of their cheap and simple patent system can be shown by many of the official reports made to Congress by their Commissioner of Patents. I will give two extracts only. In his report for 1877, the American Patent Commissioner says:—"It cannot be doubted, I think, that our marvellous growth and excellence in invention are due to the stimulus given by the protection afforded by the law. There are few valuable inventions which have not been the result of long study, and which have not required the expenditure of time and capital to perfect and bring into use—expenditures not to be expected unless there be held out the hope of reward.

"The records of this office as well as the history of manufactures, show the immense labours and achievements of inventors during the last half-century, but the end in no department is yet reached, the fields of invention are exhaustless, and under protection wisely given, the future will be richer in invention than the past." Again, in his report for 1879, the American Patent Commissioner, says:—

"The constitutional provision which confers upon Congress power to promote the progress of science and useful arts by securing, for limited times, to authors and inventors, the exclusive right to their respective writings and discoveries, evidently imports, not that inventors are hateful monopolists to be taxed by the Government, but that they are public benefactors to be encouraged and rewarded. That this is the true theory the experience of our people with their patent system during the past century abundantly proves.

"This being the constitutional theory, and also manifestly the just theory, of the relation of the inventors to the public, it is alike unconstitutional and unjust to mantain in its present condition the legislation affecting inventors by imposing upon them, in future years, the special tax which amounted to the sum of 154,495·32 dollars during the last year. It is the obvious requirement of justice and of the Constitution that one of two things be promptly done—viz. either that the fees exacted from inventors be reduced to the amount which the Patent System costs the Government, or that the surplus be expended in improving the facilities for the prompt and thorough

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examination of their applications, and for the efficient performance of the other work which they pay the office to perform."

It appears from this that the American Patent Commissioner considers the present low stamp duty of 7*l.* unnecessarily profitable, and therefore unjustly high, and he consequently proposes to reduce it!

The well-known paper, the *Scientific American*, says, "In the United States the main idea is that the inventor of any new and useful device is conferring a benefit upon the nation, and should, therefore, be protected in his invention. This is the correct theory, because it has succeeded in producing such astonishing results that other nations are gradually adopting it." Innumerable extracts to the same effect might be given from the leading scientific papers of America.

In the following table I have placed in parallel columns, for ready comparison, the averages of the transactions of the British and American Patent Offices for the ten years 1870 to 1879.

COMPARATIVE TABLE OF AVERAGE RESULTS FOR THE TEN YEARS 1870–1879.

	British Isles.	United States.
Receipts	£158,280	£143,049
Expenditure	£48,063	£125,254
Profit	£110,217	£17,795
Stamp duties on one patent	£175	£7
Maximum duration of patent	14 years	17 years
Average " "	5 years	17 years
Number of patents applied for	4496	19,770
" " granted	2980	13,355
Number of applications refused or abandoned	1516	6,415
Number of grants paid £50 duty	820	—
" " £100 duty	253	—
Number of grants killed by £50 duty	1851	—
" " " £100 "	436	—
Percentage of applications granted	66·28	67·55
" " " refused or abandoned	33·72	32·45
Percentage of grants paid £50 duty	30·70	—
" " " £100 duty	11·18	—
Percentage of grants killed by £50 duty	69·30	—
" " " £100 "	19·52	—
Percentage of grants lasting the full term	11·18	100·00
Population	34,500,000	50,900,000
Number of persons to one patent granted	11,577	3811
Ratio of amount of duties on one patent	25	1
Ratio of number of patents granted (Allowing for difference in population)	1	3
" " " in force (Allowing for difference in population)	1	8
Average cost to inventor for one patent, including patent agent's charges	£190	£19
Technical examination of applications	None	Careful
Inventions invalidly re-patented	Frequently	Rarely

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We see from the above table that in the United States three patents are granted to one here, after allowing for the difference in population. The United States thus stand forth to the world as having altogether eclipsed the mother-country in practical invention, and our own experience tells us that they are steadily overtaking us as an industrial nation; nor can we be at all surprised at this when we see that the British inventor, on whom we are dependent for improvement and advance, is so heavily weighted for the first place. The stamp duties on one patent in this country would pay those on twenty-five patents in the United States; we may therefore fairly say that the British inventor is handicapped twenty-five to one in favour of the American inventor, and it is to be most carefully remembered that in handicapping the inventor we handicap the nation. My object is not to ventilate any real or supposed grievance of the inventor, but to point out that our present patent duties, which are the most oppressive in the world, are a serious injury to the whole community, and actually obstruct the fountain of our prosperity, whereas considerations of self-preservation should cause us to clear its channel, and do our utmost to increase its outflow.

The majority of our inventors are mechanics, whose daily occupation is with machinery and mechanical processes of every description, and who therefore have the greatest opportunities of seeing defects and thinking out improvements; they want only the incentive to produce innumerable improvements. The specialty of American invention is labour-saving tools, and it is chiefly by means of the excellence and economy of their labour-saving tools, that the Americans are able to successfully compete with us. To take one instance mentioned in the *Times*, of the 26th December, 1878:—"In the Waltham factory, with the aid of machinery, the labour of one man is equivalent to the production of 150 watches annually; whereas in England and Switzerland only forty watches per annum are produced by each man employed in the trade. There is scarcely a branch of mechanical industry into which the inventive genius of the new England people has not introduced labour-saving machinery, which chiefly enables the manufacturers to sell their goods in those States on which they are almost dependent for the raw material, and even in European countries which have great natural resources and a superabundance of cheap labour."

The Americans do not surpass us by any superiority of brain, but by superiority of opportunity and inducement to develop their ideas. In the United States a patent is within reach of every mechanic; in England it is a venture for a capitalist;

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hence the superiority of the former country in the sphere of invention. Many of their successful inventors are emigrants from this country. Last year alone nearly 9000 of our skilled workmen, besides 3224 miners and quarrymen, emigrated to the United States. The number of our skilled emigrants to all other countries put together do not amount to such high figures. What mechanic here, earning 2*l.* or 3*l.* a week, can afford to pay 175*l.* in stamp duties alone? If his invention is likely to be of much use it is to his obvious advantage to emigrate, and become an American citizen, when he will have to pay in stamp duties on his patent only 7*l.*, and will also gain three additional years. The difference of 168*l.* is like a premium given to him by the American Government. Moreover, an inventor can more readily do without the aid of a patent agent in the United States than he can here, as the American law is so much more simple than ours. The United States are thus continually obtaning first-class men, the grist of the country, while we are as continually losing them.

To remedy the present deplorable state of things, the following scale of stamp duties on patents has been proposed by Mr. John Standfield, who first directed my special attention to this subject.

MR. JOHN STANDFIELD'S PROPOSAL.

DURATION OF PATENT, 21 YEARS.

On application (to cover cost of Provisional Protection), stamp duty	£2
On filing final Specification (to cover cost of printing, &c.)	3
Total stamp duties on granting each patent	£5

Provisional protection to be granted for one year. Mr. Standfield proposes to do away with all stamp duties on certificate of notice to proceed, on warrant of law officer, and on sealing letters patent, also to abolish all subsequent duties, such as those now levied of 50*l.* before the end of the third year, and 100*l.* before the end of the seventh year, and to substitute for them an annual tax of 2*l.* to commence with, which should be reduced to 1*l.* 10*s.* as soon as the state of the Patent Office funds would permit, and similarly further reduced to 1*l.* The letters patent should not be sent to the office to be stamped as they now are, but a copy of the Patent Commissioners' Journal, containing an acknowledgment of the payment, should be sent to the patentee, and considered as the official receipt. Mr. Standfield adopts the provisions of the Patent Bill of Mr. George Anderson, M.P. for Glasgow, to reduce the stamp duties on the certificate of record of notice of objections, on

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application for disclaimer, and on caveat against disclaimer, to 1*l.* each. He would make the annual stamp duty to become due every first of January, but to provide for the accidental neglect to make payment by that date, he would adopt Mr. Anderson's scale of increased payments, which, if made within the following year, would prevent the patent from becoming void. The scale is as follows:—

SCHEDUDE OF FINES FOR POSTPONED PAYMENTS.

If paid within three months after due date, 25 per cent. on the duty then due.
If paid not within three but within six months after due date, 50 per cent. on the duty then due.
If paid not within six but within nine months after due date, 75 per cent. on the duty then due.
If paid not within nine but within twelve months after due date, 100 per cent. on the duty then due.

Failing these payments the patent would of course become void. There should not be any certificates of addition to a patent granted, as the proposed small stamp duties would render them quite unnecessary, and they are open to great abuse.

There can be little doubt that when the attention of the profession is thoroughly roused to the loss the nation is now suffering in consequence of the exceptionally heavy taxes to which our inventors are now subjected, some energetic Member of Parliament will be induced to take up, nay, will be glad to have such a stirring question to take up in Parliament, and inumerable petitions will flow in to his support, so that some such excellently cheap and simple law will be passed.

With regard to the question of an official technical examination for patents, no doubt the American plan has been found to work well in practice, but we could probably improve upon it by not giving the examiners absolute power to reject an application for a patent; they should be advisers only, allowing the applicant to take out a patent at his own risk if he felt sufficient confidence in the novelty and utility of his invention after receiving the report of the examiners. In the case of an action against him for infringement, the adverse report of the examiners on his application would throw the whole onus of proof on him. But this question of technical examination, and also that of special arrangements for the trial of infringement cases, are insignificant compared with that of reducing the stamp duties so as to cover expenses only, and thus place a patent for invention within reach of that class from which by far the larger

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number of inventions emanate. The great mistake is in making the Patent Office a revenue-producing department instead of merely self-supporting. At the present time the revenue derives a sum rather less than 145,000*l.* per annum from the Patent Office, but this sum is obviously nothing compared with the immense revenue derived indirectly from our extensive mechanical industries, nearly all of which are the result of patented inventions. There can be no doubt that our present mode of obtaining this 145,000*l.* directly, causes the loss of a vastly greater revenue, which would be indirectly derived from manufactures and improvements which the latent invention of the nation is prevented, solely, by our oppressive patent law, from getting established. It is impossible to calculate the enormous indirect loss the nation as a whole suffers from our present exorbitant scale of patent stamp duties, which, we have seen, drive abroad and stifle a large proportion of that inventive faculty upon which alone we are dependent for holding our place among the nations, and which might, if not so hampered, save a considerable number of the lives now annually lost in preventable accidents, and might find employment for many who are now unable to obtain work, and whom, in consequence, we have to support in idleness. Our action may be compared to that of a husbandman who, having precious seed to his hand, allows but a small portion to flourish, permitting a considerable portion to die unused, and throwing another considerable portion away. It may well be asked, how can we expect a good harvest if we destroy and cast away so much of the seeds?

Explanation of the Diagrams.

As a graphical representation of ratios is far more realistic than mere statements of figures, I have had two diagrams made, which I think explain themselves. The "scale of stamp duties" clearly shows to the eye the great difference between the oppressive British system and the light American system. It will be observed what a small insignificant block represents the duties of the United States, and what a large block is required to represent the duties of this country. The "scale of patents" shows the opposite results of the two systems. Looking first at the lightly shaded blocks, we notice the great length of the American compared with the diminutive size of the British block.

Comparing the two diagrams, we see that small stamp duties produce numerous patents, but heavy duties produce only few patents. Looking once more at the British block of patents

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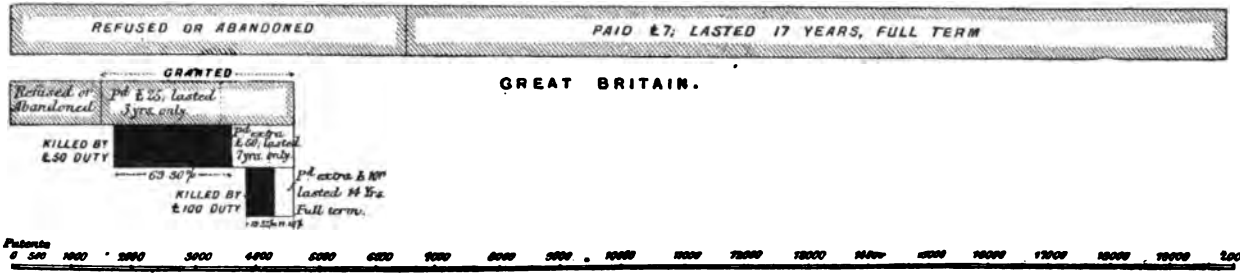
SCALE OF PATENTS.

UNITED STATES.

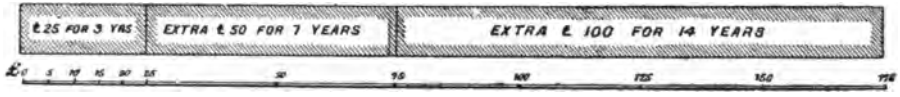


GREAT BRITAIN.

SCALE OF STAMP DUTIES.

UNITED STATES.

GREAT BRITAIN.



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granted, we see that the larger portion of them, viz. 69·30 per cent., were killed by the stamp duty of 50*l.* at the end of three years, as shown by the larger black block; and that of the comparatively few that were able to pay this duty the larger portion, viz. 19·52 per cent. of the total numbers granted, were killed by the 100*l.* duty at the end of seven years, as shown by the smaller black block, leaving only the miserable proportion of 11·18 per cent. of the total number granted, to last the full term of 14 years, as compared with the whole number, that is 100 per cent., of the American grants which lasted the whole term of 17 years, for which privilege they each paid only 7*l.* against our 175*l.*

DISCUSSION.

Mr. HINDE PALMER, M.P., said that he was extremely obliged for the opportunity of listening to the very able paper of Mr. Grierson. He hoped that the paper would be circulated so that Members of Parliament might have an opportunity of reading it, for it appeared to him to put in a most clear and succinct way the arguments in favour of granting patents upon a system different from that which now prevailed. His (Mr. Palmer's) name was on the back of the Bill which had been introduced by Mr. Anderson, and he thought that that Bill, as far as it went, was one which ought to be adopted. In the two sessions of 1871 and 1872 he served on a select committee of the House of Commons upon the question of patents. That committee examined people of eminence connected with the administration of the patent law, among whom were Lord Romilly, Master of the Rolls, and various judges who had had to deal with the law, and a number of inventors and engineers. The committee made a report, but there was a defect in that report, inasmuch as the committee did not directly recommend a diminution in the expense of taking out patents, though they certainly did recommend that the charge for patents should not be more than would cover the expense of the administration of the Patent Office. When one came to compare 175*l.*, the cost of an English patent, with 7*l.*, the cost of an American patent, the difference was so great that one naturally began to inquire what the effect must be upon inventive genius. The effect had been mentioned in the paper that evening. A comparison of the numbers showed that, as the author had very justly said, the inventive powers of England were handicapped in competition with other states. He himself introduced a bill into the House of Commons in the Parliament of 1868 for effecting

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an improvement in the patent laws; and one of his propositions was to reduce, by one-half, every one of the items in the scale of charges. He was, however, inclined to think that that reduction was not sufficient. While the actual expenses of the patent administration, and of the offices connected with it, were a small figure, nearly 150,000*l.* of surplus income went to the Consolidated Fund of the country. This seemed to him to be an improper, absurd, and injurious way of raising a revenue. It seemed to him that there was everything to be said in favour of a reduction of the patent duty. The last report of the Patent Commissioners showed that the aggregate amount of the surplus income which had been paid into the Consolidated Fund since the passing of the Act of 1852, as the product of the charges upon patents, came to very nearly two millions of money. Mr. Gladstone during his government in April 1868 took one very important step towards clearing the way for a reduction. Up to that time the law officers of the Crown had been in the habit of receiving a very large income indeed out of the patent fees, dividing between them about 10,000*l.* or 12,000*l.* a year. This payment, of course, increased their income to a very considerable amount, and it had always been an obstacle in the way of getting a reduction of the patent duty; but Mr. Gladstone took the very wise step of placing the law officers of the Crown upon a certain fixed salary, and took away from them the income which they had derived from the patents; and they got on extremely well, notwithstanding. It was quite due to the late Government to state that they made certain attempts from time to time to amend the patent laws by the introduction of bills for the purpose. Lord Cairns introduced a bill some few years ago to amend the patent laws, and it was continued year after year during the existence of the late Government, but, unfortunately, it never made any progress, and although the select committee to which he had referred made their report in 1872, and they had now reached 1880, nothing whatever had been done. He had noticed that a deputation waited upon Mr. Chamberlain, the President of the Board of Trade, a few days previously, and that Mr. Chamberlain had said that he was very favourable indeed to a great alteration in the patent laws for the purpose of removing obstacles in the way of the inventive genius of the country. He (Mr. Hinde Palmer) was therefore in hope that, if some practical measure were introduced, they would get the Government to take it up. It was very difficult for a private member to carry any bill at all unless the Government would lend him a hand, or adopt it themselves. The great thing was to bring pressure to bear upon the Government for

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an alteration of the law. His object in coming to the meeting that evening was to ascertain what were the opinions of a body of intelligent and experienced gentlemen like those whom he saw there. His humble exertions would be at the service of the inventive genius of the country for the purpose of helping on as much as possible, a reform which should encourage instead of retarding its energies.

Mr. A. T. WALMISLEY said that it was very gratifying for Englishmen to hear a good character of themselves and to be told that they were the most inventive beings on the face of the earth, but it was not much use for them to be inventive if obstacles were thrown in their way by an obstructive patent law. He thought that it must be the unanimous opinion of them all that some great reduction in the patent duties was needed. Considering that America was an agricultural country and Great Britain a manufacturing one, and that Americans had to pay more for their material, and in many cases for their labour, how was it that they could undersell Englishmen in the English markets? It was because of the invention of labour-saving machinery, and what Englishmen needed to do was to encourage the invention of such appliances. The statement which Mr. Grierson had put forward showing the small percentage of patents that were carried out to the full term of fourteen years showed at once how English inventors were handicapped by the excessive duties that they had to pay. The greatest reform needed was not abrogation, but development. Capital and labour must always go hand in hand; but it did not follow that the inventor should always work without the aid of the capitalist. He must, however, have the opportunity of working out his patent, and invention ought to be greatly encouraged by a revision of the duties. It would be a great work to reduce the red-tapeism of the Patent Office; and as to the examination of patents it ought to be made the duty of an examiner not to inquire into the utility of an invention, but only to see that the specification was clearly worded in order to avoid legal difficulties afterwards in inquring into the rights of the patentee. He thought that their best thanks were due to Mr. Grierson for bringing the subject before them in so able a manner.

Mr. THOMAS PORTER said that Mr. Standfield's proposal for reducing the stamp duties on patents from 175*l.* to 5*l.* really took one's breath away. He did not see how the proposed reduction could have been arrived at. If they could be convinced that 5*l.* would pay for the cost of investigation and other office expenses, they might come to the conclusion that 5*l.* was a fair amount, but he (Mr. Porter) ventured to think that even with

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the large amount which had been saved on patent duties and passed on to the Consolidated Fund, there would not be much available for investigation out of a 5*l.* stamp duty. The proposal of 5*l.* was put forth in the abstract, without any clear proof of its sufficiency. He felt that if the cost of a patent were reduced to such a very low sum, it would make patents very tiresome and very irksome, for every inventor of the most simple thing would be able to take out a patent. Even at present many people were rather afraid of encouraging patents for inventions which were really valuable, but if the cost was reduced to such a small sum as 5*l.*, one would be afraid to use any small thing lest he should be infringing somebody's patent. They might go too far in reducing the cost. The circumstances surrounding England were not necessarily the same as those surrounding the United States. England was a "tight little island" by itself, and the United States was a vast country, and what might be applicable there was not necessarily applicable here. It had been said that English patentees had generally been men of wealth. He did not think that that statement was quite borne out by facts. Men of wealth had been patentees, and had sometimes nearly ruined themselves by being such. He could mention the names of several very eminent patentees, who had not been in a wealthy position and who did not start with wealth. He thought that they must come to the conclusion that the duties on patents were somewhat high, but at the same time there was a great difference between bringing them down to 5*l.* and keeping them at 175*l.* Probably about 80*l.* or 100*l.* or some amount between the two extremes might with profit be adopted. But he was of opinion that the proposal to reduce the cost to 5*l.* would not be found to be practicable or desirable.

Mr. JOHN STANDFIELD said that he was sure that their best thanks were due to Mr. Hinde Palmer for attending there that evening, and also to Mr. Anderson, the honourable Member for Glasgow, for his endeavours to obtain a considerable reduction in the patent duties. The Bill also bore the names of Mr. Broadhurst, the member for Stoke, and of Mr. Alexander Brown. To these gentlemen also, thanks were due for their endeavours to obtain a lower rate, so that Englishmen might be put on a fair footing with their competitors in the United States, in Belgium, and in France. The amount paid in England was twenty-five times as much as the charge which was made in the United States; and it went forth to the world that Americans were three times as inventive as Englishmen, simply because Englishmen were prevented by the high stamp duties, from taking out patents. Although he had proposed that there

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should be a 5*l.* payment in the first instance, he had also proposed an annual payment of 1*l.* or 2*l.* to the end of the term of twenty-one years. This would bring the total cost to 25*l.*, which was more than three times as much as was paid in the United States. He believed that it would be very unwise to tax themselves more than three times the amount that their American competitors were taxed. It was very hard on English engineers and artisans that at the present time they were driven from their homes to carry their inventions to America in order to patent them. In America the patent cost 16*l.* less than the cost in England, and the protection was for seventeen years as compared with fourteen years in this country. He believed that the 141,000*l.* of surplus which was raised annually out of patents in England, robbed the country of many millions. It drove the country to import from the United States what our own people were anxious to manufacture. He regretted to see our shops filled with American manufactures, while our own people were starving for want of employment, and this result could be clearly traced to the excessive stamp duties which were demanded in this country English engineers were not less inventive than Americans. English engineers have invented and are still capable of inventing the mightiest engines, both of peace and war, but looking at the number of patents in the different, countries, it would appear that Americans were three times as inventive as English people, and that the Belgians were nine times as inventive. A deputation of railway servants waited upon the President of the Board of Trade the other day, to ask whether he could not do something for them in the way of reducing the great number of accidents which occurred among railway servants on our railways, by which accidents about a thousand lives were lost annually. He thought that it was a great pity that the deputation should have been sent empty away, without being told that a bill was about to be brought into Parliament, and that in future science would be allowed to come to the rescue. He thought that if patents were granted as cheaply in England as in the United States, the number of lives which were annually sacrificed on our railways would soon be reduced from one thousand to five hundred. During the present year, six thousand lives had been lost in our coal pits alone. Half this number might have been saved if there had been more improvements in coal-cutting machinery and winding gear, and if the cages had been made self-supporting in case of the breaking of ropes. Indeed it was impossible to estimate the number of lives which inventors could save if they were allowed to do

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so. They might also be the means of saving lives at sea. He believed that altogether we lost no fewer than twenty thousand lives annually by accident. In all probability ten thousand of those lives might be saved if inventors were allowed to come to the rescue. Again, large numbers of lives were sacrificed through fever and diseases, brought about through the want of improved sanitary appliances. It was the duty of this Society to point out to the Government, that if patents were granted as cheaply as had been proposed, a great number of lives might be certainly saved. Manufacturers tools wanted improving, so that England might win back many of its lost industries, and not only hold its own, but gain new victories in trade.

Mr. PORTER, in reply to a remark of the last speaker, with regard to the want of improved sanitary appliances, said that they had no end of sanitary inventions, but what was really wanted was that some great power should see that really useful inventions were used. The Metropolitan Board of Works ought, by a revision of their Building Act, insist that all houses should be provided with sanitary improvements. Until the Metropolitan Board of Works could take the matter up, engineers might invent till the world's end without effect.

Mr. E. J. WATHERSTON said that some years ago this country was wise enough to throw down those ridiculous barricades which had existed against the import of foreign productions, and to go in almost entirely for Free Trade. It seemed to him a great pity that they did not there and then erect sensible barricades, by altering the patent laws, and by establishing a system of technical education. Nothing could be more unwise than to handicap manufacturers by means of the prevailing patent laws. He had been in America, and had seen the operation of the patent laws there, and had found that some of the greatest patents that had been taken out were for inventions of poor men, therefore it was most important that patents should be cheap and not dear. English workmen were totally unable to spend 175*l.* on a patent, and hence they were very much disposed to keep their inventions to themselves. One of the speakers had said that, although 175*l.* was a great deal too high, 5*l.* was too low, and that therefore there ought to be a mean between the two figures. To that proposal he (Mr. Watherston) would say, let them put themselves on a level with the foreigner, who, if not beating English manufacturers out of the field, was certainly going a very long way towards doing so. Referring to the imports which came into this country, he found that in 1854 England imported 152,000,000*l.*, and in 1878, she imported 366,000,000*l.* worth of goods. He was a

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real, genuine free trader, and therefore he would not for one moment say that there was anything wrong in our importing 366,000,000*l.* of goods in the year 1878, but, as a manufacturer, he considered that it would be greatly to this country's advantage if the figures were reversed, foreign goods being kept out by the excellence of our own productions. He believed that there could not be a more foolish tax than that upon invention. It was altogether wrong, in principle and in practice. The honourable Member (Mr. Hinde Palmer) had stated very precisely the views which he (Mr. Watherston) held, an allusion had been made to the Waltham watch manufactory. Two years ago he visited that manufactory, and saw the labour-saving machinery which was in use there. The principle in America was, that all the machinery for the works of any industry was made upon the premises of the manufacturer; the effect was that the workpeople acquired a love for labour-saving machinery, and their minds were directed to perfecting and improving every machine in the place. If a mechanic found that a machine did not work rightly, he could go down into the smith's shop and there and then get an alteration made, possibly resulting in an invention. There was the whole secret of the thing. One result was, that the workmen were constantly thinking out new ideas, which they could immediately put into practice, and hence many improvements were made, and in consequence of the cheap patent laws, many patents were taken out. He found this to be the case, not only in the Waltham watch factory, but in Providence, Rhode Island, and generally throughout the great manufacturing districts of Massachusetts and Pennsylvania.

Mr. CONRADI, in replying to some remarks of the last speaker, said that he wished first to point out if a workman who was in another person's employment made an invention, say in improving a tool, a piece of machinery, or otherwise, the invention belonged to the master if it was made during the working hours, inasmuch as the workman's time belonged to the master. Had the invention been made in his spare time, it became the workman's property; but as artisans do, on the whole, not earn more than sufficient for the urgent requirements of life, they had not the necessary means to carry out the invention unless they found a party to provide them with means, or to work it for them. He believed it was even a rule that no employé of the Government was entitled to take out a patent unless he quitted the service of the Government. As to the reduction of the patent duty which Mr. Standfield had in view, he (Mr. Conradi) believed that it would be beneficial

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to the poor inventor; but rich persons would have the benefit as well, therefore the cheapening alone of patents, without at the same time offering assistance to introduce the patent, would not achieve the desired result to help substantially and especially the poor inventor, which the author seems to have in view, by proposing the cheapening of the Government patent fee. When a patentee brought out an invention, it could not be brought into general use without the old forms of tools, in which a large amount of money had been invested, being thrown aside. Consequently a very heavy struggle was necessary in order to induce manufacturers to discard their old tools and reinvest money by adopting the new invention. It seemed therefore to him that in most cases a poor patentee could not succeed in getting his patent adopted without the assistance of parties who had the means to bring it into the market, by the sacrifice of money, time, perseverance and patience. He agreed that it would be a great benefit to have cheap patents, if at the same time means could be provided to help the poor artisan to introduce and to work his patent; as certainly in cases, as mentioned by the previous speaker, of inventions or improvements made by workmen in their daily professional occupation in the manufactory, no master would assist his workman, who had invented or improved a tool or a machine of any kind, to make it the subject of a patent for his workmen's private benefit. He thought it might be possible to make arrangements, by the Legislature, that the surplus income from the patent fees, instead of going to the Consolidated Funds of the National Debt, should be applied by the Government to institute a national fund to assist poor patentees to introduce and to work their inventions, if the patents were, after examination, found thoroughly good; as the obtaining of a patent by high or cheap fees, without supplying the means to work it, was, for the poor inventor, of no avail at all. To his knowledge, private institutions of this kind were already in existence; but they do more to increase the expenses already incurred by the registration fees; they want to see beforehand whether the patent suits them or not, and in most cases it is carelessly dealt with and refused. Mostly, only inventions were accepted which cost a trifle to manufacture, being objects of fancy for the easy taste of the people and of great consumption, so that those institutions were more money-making concerns for themselves than of any help to the inventor. If now, in regard to obtaining the patent cheaply, something was done with the intention to help the poor inventor, it could perhaps be done as in Germany; as there, if a patentee proved that he had no means, the

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government granted him a patent free for three years, and in the third year, if the patent had been worked, and showed some commercial success, the patentee began to pay the government duties.

Mr. HORSLEY, said that he believed, with regard to the principal manufacturers in England, that if any of their workmen had a good invention, and laid it before them, they would find the inventor funds and help him to bring it out. He did not think that any good mechanic in England would leave his home and go to America for the sake of saving 160*l.* in the cost of patenting an invention, for after all the patent might not succeed in America, and the patentee might lose the money which he had spent in going to America. The largeness of the amount of imports into this country was not due to the high cost of patents here. The labour question must be looked to in this respect. English inventions which had been patented in this country were being manufactured in Belgium, and sent over here to the extent of thousands of pounds' worth annually. This was due to the high price of labour in this country as compared with other countries. At a railway on the Continent they wanted a thousand men, and they offered them 1½ liras a day, which was equal to 13*d.* or 14*d.*, and they got men easily. At some works with which he was connected in the same country a stoker was paid 1½*d.* to 2*d.* an hour and other men were paid 4*d.* an hour. He admitted that the cost of a patent was high.

Mr. PENDRED wished to ask Mr. Grierson whether he could add to his exceedingly valuable tables any statement of the profits that had been made by inventors—in other words, how many of the patents had been remunerative. He thought that the table as it stood was incomplete without that information. The mere fact that a patent had been taken out did not prove that it was of any value whatever to the inventor. They had heard a great deal of labour-saving machinery which was invented in the United States, and it had been said that in consequence of the advantages afforded by such machinery patentees in the United States were able to compete with English manufacturers. He (Mr. Pendred) wanted to know why English manufacturers did not import the American machinery into their works. There was nothing to prevent their using it. As to the cost of a patent, the patentee did not pay the 175*l.* all at once. He could get a patent for three years for 25*l.*

Mr. H. S. COPLAND said that he had had considerable interest in patents. He believed that the present cost of

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obtaining a patent was too great, but he did not think that he would go so far as Mr. Standfield in the way of general reduction, he would make the rates of payment upon patents more in accordance with the principles under which the rates are payable under the Belgian patent law. He would take 5*l.* as being the amount to commence with and make it a progressive annual payment, commencing with 1*l.* at the beginning of the second year, and increasing by 1*l.* each succeeding year over a term of twenty-one years, that being the extent of the period for which patents are granted in some other countries. It was found that a man who took out a patent in this country might remain from three to seven years before he could get any return. The first 50*l.* duty very often killed his patent right off, through omission to pay the 50*l.*, and he might find that his capital and labour had been thrown away through the patent being forfeited, and people who had been watching it might then take up, and work it. And whereas they and others benefited by the invention, the patentee would be at considerable loss. He had himself been a sufferer in this way, and therefore he could speak from experience. A comparatively small fee in the first instance would not press unduly on the inventor, and would encourage invention. Whereas the annual patent fees would increase in the same ratio as successful inventions became remunerative, and though the aggregate amount of annual fees payable over a term of twenty-one years would greatly exceed the 175*l.* now payable, it would not press so unduly on inventors as at present. He thought that if a patent was a good and productive one, the patentee should certainly pay something to the revenue of the country in the form of patent fees commensurate with the advantages he derived from the protection afforded him by the grant of letters patent, and therefore the annual amount ought to be an increasing one. A similar system of progressive annual payments worked very well in Belgium, and he considered such would also be the case in this country. Many inventions were frivolous, and proved of no use either to the inventor or to others. By progressively increasing the annual payments the worthless patents would be killed off at an earlier date, and before a patentee incurred serious loss; and by being taken off the lists, they would not prove such an impediment as at present to those who were working in a useful direction. There was another point which required consideration in any amendment of the patent law, viz., according to the existing law, at the end of the third and seventh years, the patentee had to pay the respective duties of 50*l.* and 100*l.*, and if the

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money was not paid the patent lapsed without any appeal whatever, except the very expensive process of a special Act of Parliament. In some cases the failure to pay was due to the fact that the patentee overlooked the date for payment, or if a patent had been assigned, that the assignee of the patent for the time being neglected to pay the stamp duty at the proper time. If the patentee went to the patent office even twenty-four hours after the money was due he could not get the stamp impressed. In Belgium, Austria, Italy, and several other continental countries, patentees were allowed a certain limited period, such as from three to six months, within which the stamp duty could be paid with the addition of a comparatively small fine. He thought, most decidedly, that some provision of that kind ought to be included in any new patent law which might be passed in this country. Also that the Patent Office should give the patentee and the registered holder of the patent due notice of the date on which fees will become payable, and their amount. From the very fact of the payment in England being intermittent and at long intervals the patentee is very liable to overlook the payment, whereas, if payable at a fixed annual date, and due notice were given, he would be no more likely to omit payment, if he wished to retain his patent, than in the case of his rent. The period of grace would also cover the case of omission due from absence abroad or other unforeseen cause. The total cost of a patent upon the plan which he proposed would be about 21*l.*, extending over a term of 21 years. Taking the average number of patents throughout the year, that sum would pay the expenses of the Patent Office, and leave a very good margin, even allowing for the expiring of a large proportion of patents at an early period of their possible existence. He doubted whether the amount proposed on Mr. Standfield's system would be productive of sufficient income to pay the expenses of the Patent Office, if they took those expenses even at their present rate.

Mr. LE GRAND said that during the last fourteen years he had had some considerable experience of patents. He was firmly of opinion that the English patent fees were unjust and exorbitant. He thought it was somewhat premature at the present moment to lay down any hard and fast line as to what the fees ought to be. Perhaps experience would teach them the right amount, but if they could get only half a loaf it would be better than none. If they could get in the thin end of the wedge by only reducing the fees to one-half, they would make a step in the right direction. He considered that the Belgian plan of making the fees progressive was worthy of

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much consideration. As the patent law of England stood at present it simply gave a man a licence to go to law. There was really very little protection at all. If a man had a valid patent, and wanted to enforce it, he had to set in motion the Court of Chancery. This was a very expensive matter, and not even a comparatively wealthy man cared to undertake it. Much had been said that evening about American patents, but he thought that even the valuable statistics which had been put before them must be taken *cum grano salis*. He was very certain that a large proportion of American patents were taken out for things which he could only call gimcracks, such as toothpicks, potato-peelers, and other "notions." With regard to any legislation in this country, he should advocate that in addition to scrutineers of patents there should be counsellors or advisers to advise men who applied for patents as to the utility of their inventions. One defect which had existed in the American patent law, but which had been recently abandoned, was that a patentee was compelled to construct a model. That requirement in many cases put inventors to needless expense, and it had led to the production of a large number of models, which had been consigned to the limbo of cellars and had rotted away long ago, for which it had been impossible even to find places in museums. He thought that many of the hindrances in bringing out inventions lay to a certain extent with the inventors themselves. Many inventors had a tendency to kill their inventions by demanding exorbitant and absurd prices for the things which they brought out. He had known numerous cases in which a patentee had asked as much as ten times the cost of the article which he had invented. He had been told that in France it was a common practice to ask a very small price at first, and to increase it as the article proved its utility and came into demand. Returning to the first part of his remarks, as the law stood at present in this country the same invention was sometimes patented over and over again. Inventors in such cases were practically robbed of their money.

Mr. ASTON asked whether the patent law was for the benefit of the inventor or for the benefit of the country. In his view it was for the benefit of the country. He believed that if the benefits obtained by the country from the patent law during any period of the last forty years and the benefits derived by inventors during the same period could be put in a tabular form, like one of those which had been prepared by Mr. Grierson, that the figure representing the benefit received by inventors from their patents would be so very small as com-

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pared with the other figure that it would be altogether insignificant. He should advise those who wished to reform the patent law not to go for different schemes, but to go for one scheme, and to ask for more than they expected to get. His own opinion was that a patent ought to be as cheap as a copyright. He should advise them to go for something which was in existence. Mr. Standfield's plan was not in existence, but the American law was. He should say that 7*l.* was not low enough, but certainly it was quite high enough to pay for any patent.

Mr. GRIERSON, in reply, said that, among other countries, Belgium had been mentioned in the course of the discussion. The reason he had chosen the United States as an example in the paper was that it happened to be the only country in the whole world in which the conditions of working patents were the same as in England. At the present moment in the United States no models were required, and there was no compulsory working within a certain limited time, or periodically. There was, however, one difference in favour of the United States, and that was that there was an official technical examination of all applications for patents. It was found by patent agents that after this careful technical examination of applications in the United States it was a rare thing for any invention to be invalidly re-patented. In this country there were no examiners, and hence the number of patents which were void from the day on which they were taken out was very great. Mr. Anderson's Bill was a vast improvement on the present law, and the country ought to be thankful if they could get such an Act passed; but while they were upon the subject of improvement they might as well go as far as they could with any chance of success. He thought that if Mr. Anderson were more practically engaged in engineering he would go further than his present Bill proposed, and he should not be surprised to hear that Mr. Anderson had given up some of his present proposals upon further consideration. As to the deaths resulting from accidents, and which amounted to about 21,000 every year, most of them were preventible. What made the hardship of the present stamp duties on patents still greater, was that the Patent Museum did not get a farthing of benefit from the enormous taxes upon inventors, and the surplus money went, as Mr. Palmer had mentioned, to the Consolidated Fund or the Revenue, while the Patent Museum was, as they knew, a standing disgrace to the country. It was one of the worst things that a foreigner could see. One of the speakers said that he very much doubted whether 5*l.* would cover the cost

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of a patent. In reply to this, they could point to the case of America, where a patent cost only 7*l.*, out of which they were able to spend a vast deal more than was spent on the English Patent Office, and in addition provide for official examiners, such as did not exist even nominally in England, and there was even a proposal to reduce the cost of an American patent to less than its present amount. This alone proved that 7*l.* was more than sufficient to pay all expenses. If the Patent Commissioners considered 5*l.* too small a duty to start with, let it be fixed at 6*l.*, or even 7*l.*, the same as the United States have, and reduce it later on. One of the speakers had referred to the effect of a large number of things being imported into this country under patents held here. In those cases the inventions were first of all the subject of patents in the country where they were made, and they frequently were patented here afterwards. The patentee found that it was to his advantage to manufacture them abroad and import them here instead of making them in this country. He made everything he wanted for the whole world at his own factory, and his patent in this country prevented anybody from interfering with him. This accounted for many of the American patented articles which were sold in England. A speaker had referred to potato-scrapers or apple-peelers as being a frivolous invention, which ought not to be patented. The American inventor who could make potato-scrapers by the million could supply the world with them, and the demand for such appliances shows that their manufacturer supplies a want. It had been argued as an objection to the American system, that in this country a great many inventions could be covered by one patent, whereas the American patent law was very strict in allowing only one invention to be the subject of one patent. However, those who searched the records of the Patent Office in England would find that it was very seldom that more than one invention was included in a single patent. A man did not make inventions off the reel by the half dozen, and as a rule he patented his inventions as he made them. He had also heard it stated that patent agents would necessarily object to any reduction in the present stamp duties, because their business would suffer. He thought, however, that that was one of the most short-sighted views it was possible to take on such a subject. The charges of patent agents were not based in any way upon the stamp duties, but were based upon the work which the agents had to do. They would have exactly the same work to do for each patent, even though the duties were reduced, and if the reduction brought them more clients they would have more charges to make and obtain more

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profit for themselves. The purport of part of Mr. Conradi's argument seemed to be that they should simply stop where they were. Mr. Conradi had also said that when a new invention was introduced it was very often necessary to throw away the old machines, and that this involved a great loss of money. This was true, but manufacturers would be taking a step in advance, and, as it were, would be simply throwing away old shoes which were worn out and adopting new and improved ones. There was not much to be deplored in that. Of course the new machines were better than the old ones, or they would not alter or throw the old ones out of use.

Mr. CONRADI said that he had been misunderstood.

Mr. GRIERSON, continuing, said that it seemed rather a contradiction from Mr. Conradi, after arguing that it would be a mistake to have cheap patents, to point out Germany as an example to be followed, because in that country an inventor could get a patent for nothing for three years on giving proof of his poverty. If it was an advantage to have a patent for nothing, surely the next best thing was to be able to obtain it very cheaply. It was not quite a fair comparison to bring in Germany, France, and Belgium, for the conditions of working were so burdensome in those countries; it was necessary to work a patent within a given time, or a patentee must prove, at a very great expense, that he was not able to work it. Unless this was done, the patent became void, and the courts of law in France had not the power to grant any extension of time. There was no doubt that were it not for the conditions of working, the number of patents in Germany, Belgium, and France would be multiplied manifold. Both Germany and France now take out annually more patents than we do, and Belgium takes out very nearly as many. Somebody had said that the great advantage of high stamp duties was that it destroyed useless patents for litttle things that were called gimcracks. But what about the good patents that were killed at the same time? It had been said that to a good invention the stamp duty was only a fleabite; it is only a fleabite to the invention of a rich man, but good inventions belong more often to poor men than to rich ones, and, although the stamp duties might be by some wealthy inventors considered as mere fleabites, they had been enough to kill many valuable patents. There was no doubt that patents were allowed to lapse from mere accident in numerous cases. Mr. Standfield's proposal contained an arrangement that the fee should be due upon one particular date, just as was the case with the income tax. Such a date could be very easily remembered. One speaker had

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asked him whether he would give a statement of the profits of inventors in the United States. That seemed, on the face of it, rather a puzzler, but he was glad that he could give the information, and he would give it in this way. The profits of American inventors were, of course, the profits of the nation, and these profits were so great that American inventions and manufactures might be seen on sale in every large town, although in the manufacture of those goods the Americans paid more for material and for labour than was paid in England, and had to pay freight and insurance in addition. How could American manufacturers produce this result? The only possible answer was that an American could take out a patent at a small cost and protect himself, and make an article, and push the sale to such an extent that there was no room for a second maker of the same article. A speaker had said that patentees injured their chances of success by charging too high a price for patented articles. However, he did not see what that had to do with the question before the meeting. As to the rejection of applications for patents, the number rejected was about the same in the United States and in this country, and amounted to about 67 per cent. of the total applications. The reason of the rejection in the United States was in most cases inutility or want of novelty. Some were inventions which had already been patented, and therefore could not be validly re-patented. In this country the majority were rejected because the patentee had not the money to pay the duties. The number rejected in the United States on this account was very small. One gentleman had said he should like to see patents obtained as cheaply as copyright. That idea would altogether eclipse Mr. Standfield's proposal. A copyright was granted for forty-two years, and the cost was 5*s*., with the condition that three copies of the work should be presented to the public libraries. With regard to inventions, the real question was, Was the patent law for the benefit of the nation or for the benefit of the inventor? If it was simply for the benefit of the inventor they were only wasting time in discussing the subject. If it was for the benefit of the nation, then it was obvious that it would be best for the prosperity of the country to make a patent as cheap as possible. England was the most favourably situated of any country in the world with regard to mechanical industries, and she ought to be able to supply the world as she once used to do, instead of standing, as they must confess she now stood, in awe of the United States inventive and manufacturing powers.

The PRESIDENT said that it always had appeared to him that

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the cost of a patent in England was excessive, and even the division of the expense into three principal payments of 25*l.*, 50*l.*, and 100*l.*, did not sufficiently abate the nuisance. A patent was taken out for the benefit of the country, no doubt, though not in the first instance, for the inventor wished to benefit himself. In other directions the government assisted a man in every way. If a man had a piece of ground which he wished to open as a mine for the purpose of raising mineral, he had to pay the smallest possible tax. If he wished to carry on any other sort of business, he paid the smallest tax which the country could afford to allow; but if an inventor had made an improvement in any machine or process, and wished to obtain protection for it from the Government, or rather registration only, for that was all he obtained, he was simply fleeced. He fully agreed with Mr. Grierson and with those who had spoken in their desire to reduce the cost of a patent. Whether it would be wise to go quite so low as had been proposed, or as low as in America, he did not know. He confessed that he stood aghast at the idea of there being no fewer than 220,000 patents in force at the same time in any one country, and it struck him that those who were benefited by patents in the first instance, being manufacturers, they must be hampered in many instances by the great number of patents which they had to consider. Therefore he was not quite sure that it would be wise to make such a great reduction in the cost of patents as had been mentioned, more particularly as there were many other points that had to be considered before the actual cost of the patent to the inventor could be taken as final. The mere patent fees did not really form the whole difficulty in the matter.

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